TOPICS OF THE MONTH

Milestone of success

WHEN the history of the chemical industry in the 20th century comes to be chronicled by future historians, the development and discovery of synthetic organic high polymers will probably count as one of the most remarkable achievements. By the end of the 19th century the pursuit of organic chemistry, both theoretical and experimental, was at a very high peak. Chemists were beginning to understand that the process of polymerisation occurred in nature: in the rubber tree, the wool fibre and the starch molecule. The first known and used plastic materials as, for instance, casein, cellulose nitrate and shellac, had undergone natural polymerisation and were only extracted or regenerated in the laboratory. They could be called ' natural ' plastics as opposed to the ' synthetic ' plastics later obtained by man-made polymerisation.

One of the most far-reaching developments in polymer science was the recognition by Carothers in the thirties of polycondensation as a general method of polymerisation. From this sprang neoprene rubber, the polyamides (nylon) and the polyesters that have since played a dominant role in synthetic fibres. Addition polymerisation, probably the most important method of polymerisation, was already known in the 19th century, but difficulty in controlling rate of reaction precluded any industrial application of this method. Hence it was felt that some understanding of the mechanism was essential for the proper control of addition polymerisation. Once the mechanism had been understood, the reaction could be properly controlled. Polyvinyl chloride and later polyethylene as a result were successfully polymerised.

Some of the newer methods of effecting polymerisation derived from the original work of Ziegler and Natta have led to many striking results, especially in the field of polyolefines and the synthesis of the natural rubber molecule (cis-polyisoprene). These discoveries focused attention on orientation and, above all, on crystallinity in high polymers (phenomena which were not entirely new but which had not previously received much attention). Thus a new understanding was obtained between the relation of physical properties and structure. The co-existence of crystalline and amorphous regions having very different degrees of accessibility was then postulated.

Before polyamides had made their appearance the melting and softening points of most linear polymers had tended to be rather low. On the other hand, it was known that, by cross-linking, a material with a higher melting point could be obtained which was, however, fairly rigid and inflexible. The development of polyamides first showed that a tough, non-brittle material having a fairly good heat resistance was obtainable. Another linear polymer, polyvinyl chloride, when first used was considered too tough and unflexible and was therefore ' softened ' by means of plasticisers. This plasticisation naturally decreased its heat resistance. Eventually, and in Britain not until after the second world war, the advantages of rigid PVC for materials of construction were realised. The special feature on PVC in this issue deals with many of the applications in the plastics industry of this versatile linear high polymer.

The most apposite comment we could make about the utility and desirability of PVC as a material of construction could be that here is a classical example of a ' cyclic product,' namely one that has been made by chemists and chemical engineers and is in the end again used by chemists and chemical engineers. A most desirable and functional purpose!

Small-scale distillation

LABORATORY and pilot-plant distillation units are of considerable interest to both research and development engineers. Sufficient data on scale-up have been known for some time but very often the large number of variable factors with complicated units make the mathematics of scaling-up most complicated. It is therefore of interest to note that the British Petroleum Co. has recently designed a new type of distillation apparatus. The normal charge to this unit is 4 litres, which enables a sufficient quantity of each fraction to be obtained for subsequent analysis and refining treatment. The dimensions of the column are 36 mm. internal diam., 1,370 mm. length and 1,220 mm. packed length. The standard packing consists of stainless-steel boot eyelets which have been estimated to give a plate efficiency of 14. Packed columns, of course, largely eliminate the problem of liquid holdup, as Dr. Molyneux pointed out in our March issue.

In view of its comparatively large capacity, high throughput, ease of control and suitability for operation at atmospheric and reduced pressures, this unit gives a very high degree of fractionation. As a result, narrow boiling fractions can be analysed separately or blended in aliquot proportions to produce a number of possible refinery specification products for analysis.

A typical range of cuts prepared to a crude oil assay was:

Atmospheric pressure	15.5 to 95°C.	Light gasoline
" "	95 to 149°C.	Gasoline
" "	149 to 175°C.	Naphtha
100 mm. mercury	175 to 232°C.	Kerosene
2 mm. mercury at	232 to 288°C.	Light gas oil
" " "	288 to 343°C.	Medium gas oil
" " "	343 to 371°C.	Heavy gas oil
	371°C.	Residue

Although originally designed for assays of crude oil this distillation unit could be equally well used in the distillation of organic chemicals to obtain basic yield data.

Depleted uranium

DEPLETED uranium, a by-product of enriched uranium, may be of potential use in both the metallurgical and petroleum industries. Several American research centres are conducting studies on uranium hexafluoride which remains when U^{235} has been removed by the gaseous diffusion process. Various methods of blending depleted uranium metal with lead, tin and copper to produce a superior combination for metal bearings have been tried. At the same time tests are being conducted to determine whether sacrificial anodes of depleted uranium will prove more effective than conventional zinc and magnesium, in retarding galvanic corrosion of pipelines and similar structures.

As uranium is one of the heaviest metals known, the U.S. Bureau of Mines plant in Nevada is trying to use it in processes for separating minerals according to their different densities. Uranium is denser than ferrosilicon and magnetite commonly employed in heavy medium slurries for separation of different minerals. Hence it is expected that an application for it in the recovery of high-grade minerals may be found. At another research centre depleted uranium in the form of uranium oxide is being tested as a catalyst in laboratory-scale refining of shale oil. Further studies are necessary before the performance of this material as an industrial catalyst can be thoroughly evaluated.

The U.S., of course, has a potentially valuable surplus of depleted uranium and stockpiles of this material are growing because most nuclear applications nowadays use enriched uranium. An important problem that should not be overlooked is the slight but ever-present radioactivity in depeleted uranium. It would indeed be foolhardy and criminally dangerous to develop industrial applications for this interesting by-product without adequate protectional safeguards.

Frost reduction in soils

THE effective waste disposal of sulphite liquors is proving a perpetual worry to many countries. For this reason it is especially interesting that Canadians have been so versatile in devising practical solutions to overcome this problem. The Atomic Suspension Technique for burning slurries and waste liquors, developed by the Pulp and Paper Research Institute of Canada, is described in this issue. A further use for waste liquors is reported by E. Penner and P. Robillard in the December 1959 *Transactions of the Engineering Institute of Canada*.

During the past few years much interest has been focused on the use of chemical additives for the prevention of frost heaving in soils. Among the many additives studied was waste sulphite liquor, which consists largely of lignosulphonates but also contains smaller amounts of sugars and acid degradation products of lignin and cellulose. The effectiveness of waste liquors in reducing frost heaving has been attributed by some workers to the beneficial effect of its dispersant action when mixed with the soil, which results in greater densities and consequently lower permeabilities. Other workers believe that the high viscosity of the waste sulphite liquor solution in the pore water is the major cause in the reduction of ice segregation. Penner and Robillard, however, did not feel that these explanations completely accounted for the very large reductions in frost heaving that are sometimes reported.

From studies of ice-crystallation rates in biological systems the effectiveness of organic substances in reducing the rate of ice growth was demonstrated. Experiments were then undertaken by the Canadian workers to measure the rate of linear ice growth in sulphite liquor solutions contained in small glass capillary tubes. They found that at the same degree of supercooling the rate of ice crystallisation in waste liquors is greatly reduced below the values for pure water. The greatest reduction per unit concentration occurs in the most dilute solutions, whereas at high concentrations and large supercoolings the effect becomes logarithmic with concentration. Although the conditions are not entirely similar to the growth of ice lenses in soil, it is believed that this phenomenon in part accounts for the reduced heaving obtained in soils when treated with waste liquor.

Swords to ploughshares

THE U.S. Atomic Energy Commission has approved initiation of construction and site preparation for project Gnome in New Mexico. The project is part of the Commission's Plowshare programme (a meaningful and portentious description!) to investigate the feasibility of using nuclear explosions for peaceful purposes. During the current nuclear test suspension negotiations in Geneva, the U.K., the U.S. and the U.S.S.R. have agreed in principle on the use of nuclear explosions for peaceful purposes. The scientific results of project Gnome, like all Plowshare projects, will be made available on a world-wide basis and the United States will welcome observers from the United Nations or any of its member countries which are interested in the project.

The experimental objectives of the project are four-fold:

(1) Explore the feasibility of converting the energy from the nuclear explosive into heat for the production of electric power.

(2) Investigate the practicability of recovering useful radioisotopes for scientific and industrial applications.

(3) Expand the data on characteristics of underground nuclear detonations to a new medium (salt) which has marked differences from the tuff (a volcanic rock) at the Nevada test site in which previous underground detonations have been conducted.

(4) Make neutron cross-section measurements which will contribute generally to scientific knowledge and to the reactor development programme

Detailed studies and experiments have been conducted to assure the safety of this project, in which the detonation will be completely contained underground, and these studies and experiments have been reviewed by a panel of experts.

Cryogenics

THE term cryogenics, according to the Oxford dictionary, has been used since 1875. Students and admirers of Lancelot Hogben's 'Interglossa' would doubtless deduce the correct meaning of the word: frost production. It is coincidental that cryogenics as a science dates back to about the same time, 1877, when liquefaction of oxygen was first achieved. Following this, Nernst's third law of thermodynamics as the zero point of entropy at absolute zero, established cryogenics as a branch of physical chemistry. Cryogenic engineering, however, is a young subject and only dates back to the end of the second world war. It is concerned with developing and improving low-temperature processes and equipment, determining the physical properties of materials used in producing and maintaining low temperatures, and the practical applications of low-temperature techniques and processes. To distinguish it from refrigeration engineering a boundary of −150°C. is commonly accepted below which temperature is the province of cryogenic engineering.

In next month's issue we are publishing a special feature on cryogenics. One of the main articles will be written by Dr. K. Mendelssohn, F.R.S., of the Clarendon Laboratory, Oxford, who will describe some of the more important contributions made by low-temperature engineering, especially the industrial applications. Dr. Mendelssohn is one of the world's leading authorities on low-temperature physics, and his research team at the Clarendon laboratory has been in the forefront of many new developments in this field.

Water-softening unit

A PORTABLE water-softening unit which can be attached directly to water-lines and thus requires no pumps has been developed at the New Mexico Institute of Mining and Technology. The unit, which is quite small, works by an electric membrane process which was made available shortly after the second world war. It imparts an electric impulse to water, forcing ions into a porous membrane. The ions, when captured, are discharged into a waste stream. As a result, deionised 'soft' water is obtained.

Voltages of 250, 350 and 450 (d.c.) have been successfully used in the membrane cell. The higher the applied voltage the higher the rate at which the soft water is produced. With this unit deionised water containing no more than 5 p.p.m. impurities has been obtained from city water which previously had an impurity rate of 155 p.p.m.

The unit operates at room temperature and thus does not give off large amounts of excess heat as is the case with distillation plant. No recharging is required and the stream of deionised water pumped under normal line pressure can be elevated to storage tanks without pumping. The cell seems to show considerable promise as a source of deionised water. It is no more expensive to build than a still of similar capacity, and consumes far less power.

Italy in the 1960's

ITALY'S economic revival since the end of the war reached a peak in 1959, reported to have been the best year in that country's economic history. Production in 1959 was 9% higher than during the previous year and, in spite of this high rate of expansion, inflation was kept well under control. The chronic disease of Italy is still, unhappily, unemployment of unskilled labour. This is steadily being reduced by increasing production. The shortage of scientists and engineers felt all over the Western world has recently caused the Italian authorities to initiate belated reforms in their scholastic system.

With the entry of Italy into the European Common Market, Italians will soon begin to feel the effects of this new industrial revolution. It is fully expected that member countries of the Common Market will take advantage of investing in Italy's underdeveloped south. This should be a particularly attractive proposition to the chemical industry, in view of the untapped mineral resources which are still to be found both in southern Italy and Sicily.

Nitric acid

DURING the past few years the uses of nitric acid in the U.S. have altered so significantly that the primary outlet for this acid is now in manufacture of fertilisers rather than explosives. The greatly increased demand for fertilisers has been primarily responsible for more than doubling nitric acid production since 1951. About 75% of all nitric acid currently produced in the U.S. goes into the manufacture of fertilisers while 15% is used for explosives. The remaining 10% is distributed among a wide variety of industries, for instance synthetic fibres, dyestuffs, plastics and elastomers.

Two new processes for nitric acid manufacture were recently developed in the U.S. In the first (the Wisconsin process), air is heated in a pebble furnace to 4,000°F. when nitrogen fixation occurs, and is then subsequently cooled. The gases leaving the furnace contain about 18% nitric oxide. They are fed into the generator section where nitrogen dioxide, which has been previously adsorbed, is purged from silica gel. The hot gas stream then flows into a drying tower where it strips water from the down-coming silica gel. The water is removed from the gas stream in a cooler condenser and the cooled gases are then fed back into the drying tower where the remainder of the water in the gaseous stream is removed by adsorption on to silica gel.

The weak acid condensate from the cooler is fed to the acid tower, and the gases leaving the drying tower are filtered and passed through an oxidiser where nitric oxide is catalytically converted to nitrogen dioxide, cooled and fed to the nitrogen dioxide absorber where nitric oxide is stripped from the gas stream. The nitric oxide is removed from the silica gel in the lower section of the adsorber and may be condensed to form liquid nitrogen tetroxide or blown to the acid tower to make 60% acid.

In the second process Harteck and Dondes have reportedly obtained yields of 5 to 15% nitrogen dioxide by exposing compressed air to radiation from uranium-235. In their process nitrogen and oxygen molecules are oxidised and decomposed by fission fragments and radiation. The preferred operating pressures are over 150 p.s.i. at a temperature of 400°F. The U^{235} is incorporated into a reactor fuel matrix consisting of glass fibres.

The cost of producing nitric acid by such a process depends on the efficiency of converting nuclear energy to chemical reaction energy. Harteck assumes an overall efficiency of 50% and indicates that 1 mole of 20% enriched U^{235} will produce 70 tons fixed nitrogen or 258 tons 100% acid. The fixed nitrogen has a value of about $10,000, while 1 mole of enriched U^{235} would cost about $6,000.

Russian Journal of Physical Chemistry

THE Western world is rapidly realising that the Soviet contribution to science is far from negligible. The language barrier that has so long prevented any real interchange of scientific literature between Russia and the West is gradually being broken down and as a result the Russian language is becoming of increasing importance to scientists. Many universities are now instructing their undergraduates in technical Russian—unfortunately if they derive as little benefit from this as they have done in the past from similar instruction in technical French and German the prospect looks glum.

As part of the programme of translating Russian scientific literature into English, which both British and American governmental agencies are undertaking at present, the Chemical Society with the support of the D.S.I.R. recently published the first monthly issue of the *Russian Journal of Physical Chemistry*. The *Russian Journal of Inorganic Chemistry* has already been published in English for over a year and the next journal to be translated will be the *Russian Chemical Review*.

The translation and editing of this journal is a massive task and many people are actively engaged in it. There is a scientific editor, R. P. Bell, F.R.S., together with an assistant editor and an advisory panel of nine eminent physical chemists. This editorial committee takes full responsibility for the scientific veracity of the translated papers. The first issue contains 41 papers rather short in length, the average paper being only two and a half pages. The topics covered are extremely wide, ranging from theoretical discussions of thermodynamic functions to the measurement of physico-chemical properties. Until very recently Russian research workers have been prevented from publishing their work in any but Soviet journals. As a result there always has been a severe shortage of space in those journals and their editors have had to condense contributions as much as possible. This is particularly noticeable in descriptive sections of papers where apparatus and techniques are sometimes scantily described and often only reference is made to experimental techniques published elsewhere. From the point of Western research workers who claim that the most interesting facet of Soviet scientists is their original experimental technique, this is most regrettable, yet this can hardly be blamed on the British scientific editors who surely are to be congratulated on a notable achievement.

European magnet

THE significant business relapse suffered by E. I. Du Pont de Nemours in 1958 gave rise to some considerable re-thinking of strategy at Wilmington, Delaware. Hitherto all manufacturing activities of this large American chemical company had been situated within the United States. With the emergence of various European free trading areas it was felt that the European markets must be conquered from within; this led to the creation of a special European section of Du Pont, with its headquarters in London. In the past year the European section has gradually revealed its strategy, which is to establish as far as possible manufacturing sites in every major European country. Thus neoprene will be produced in the United Kingdom—the plant in Londonderry, Northern Ireland, is near completion. In conjunction with this, an elastomers laboratory dealing specifically with customer technical service in connection with neoprene and some of the more recently developed synthetic rubbers, is in operation at Hemel Hempstead.

Last autumn, a French Du Pont subsidiary was established for the purpose of manufacturing herbicides for the French market. To begin with, *Telvar* (monuron) and *Karmex* (88% active ammonium 2, 4-dichlorophenoxyacetate) will be produced. At the same time Du Pont established a German bridgehead with its creation of Pigment-Chemie GmbH., in which the German company, Sachtleben, owns 74% shares and Du Pont 26%. It is planned to boost the titanium dioxide production capacity of Sachtleben by making high-quality titanium dioxide for the paint, rubber and paper industries. A Belgian subsidiary was already formed in 1958 to manufacture dyestuffs and lacquers, both enamel and nitrocellulose. It is expected that this plant in Malines will start operations during this month, and that as a result all requirements for the Benelux countries will be adequately catered for. This will, of course, be the first European Du Pont factory in operation. In the Netherlands a subsidiary has been established for the production of *Orlon*, both filament and staple. A plant having a production capacity of 15 million lb. p.a. is being built in Dordrecht. Together with this a textiles laboratory has been opened in Geneva for customer technical service and this will have similar functions as the elastomers laboratory in Hemel Hempstead.

These activites show how far Du Pont are participating in the European chemical industry. It is most reassuring to find so much confidence placed in Europe's increasing prosperity. But is there not a strong bias by this major American corporation in favour of the European Common Market (the six) rather than the European Free Trade Area (the seven)?

Chemical Engineering Fundamentals—I

By K. L. Butcher,* B.Sc., F.R.I.C., M.I.Chem.E.

Most chemical engineers periodically feel a need to re-examine some basic chemical engineering principles with which they are well acquainted. Such a re-appraisal of fundamentals is not often available in textbooks, because the very nature of chemical engineering philosophy is still at present in a fluid state. Mr. Butcher of Leeds University has written a series of articles on 'Chemical Engineering Fundamentals' in which he appraises and evaluates many aspects of chemical engineering operations in the light of the present-day state of knowledge. The first article discusses well-known concepts like conservation of mass and Dalton's law as applied to a simple analysis of a flue gas mixture. Subsequent articles will be included during the next months.

THIS series of articles concerning the quantitative aspects of chemical engineering operations begins with a survey of the fundamental definitions and hypotheses upon which the ensuing discussion must depend. For this purpose, matter and energy will be considered as distinct from one another, although energy will be released or absorbed when a fixed amount (mass) of matter is transformed by chemical or physical change into the same mass having different properties.

Thus, in all the changes brought about during chemical engineering operations, the total mount of matter introduced into the zone of operation remains unchanged by the operation, as does the total amount of energy distributed in various forms such as potential energy and kinetic energy, internal or intrinsic energy, etc. However, although matter and energy are independently conserved, changes from the original state of affairs are effected and these are concerned with the arrangement of the parts of the system of substances upon which the plant operates.

Simultaneously with the rearrangement of 'matter' there is generally a rearrangement in the distribution of energy among its various forms. In practice, the net effect of these combined rearrangements is to alter the proportions of the forms of energy in the whole system in such a way that the possibility of converting energy into mechanical work is less after the operation than it was before. It is in this sense that heat is the 'lowest' form of energy for, although it may be considered as a form of kinetic energy, the velocities of the constituent particles of a body containing heat is such that no net motion of the centre of gravity of the body is observed due to this cause.

The velocities of the individual particles which are randomly 'arranged' (implying both magnitude and direction) contribute to the heat energy of the parent body. Bodies are said to be at the same temperature when the mean kinetic energy of the molecules in each body is the same.

The quantitative expression of the foregoing notions must now be considered.

Conservation of mass

This brings us immediately to the difficulty of defining what are considered to be 'basic properties' by any means other than the circular argument of a mathematical nature. We are able to detect movement, or the change in relative positions of bodies and, by comparing the ratios of the number of movements of one kind that correspond to those of another kind, we have a basis of measuring time and this, with the number of displacements of its own length that a body experiences, gives us the concept of the magnitude of motion. The rate of change of position in a given direction gives us 'velocity', once we have accepted the basis for comparing lengths, L, of bodies by means of the ratio their lengths bear to some one, 'fixed' standard body.

Mass is a property which is detectable and measurable in terms of the idea of motion or absence of motion. It is the inertia, M, of a body which, with the rate of change of velocity $\left(\frac{L}{T}\right)$ with time, T, is in turn a measure of the force, P, acting upon the body. By arranging experiments such that the force per unit of inertia may be presumed to be independent of position and of inertia, it is possible to compare the inertias of two bodies by finding conditions under which they produce forces of equal magnitude. The fulcrum and the balance enable this to be done by making possible the determination of the relative weights (inertia $\times$ acceleration due to the earth's gravitational pull) of bodies.

Thus $P = M\left(\frac{L}{T^2}\right)$, which is often termed Newton's second law of mechanics, completes our basis of physical measurements of mass, length and time, all of which are related to empirical standards. This is not the

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place to discuss questions of absoluteness or relativity.

In passing, it may be added that the first and third laws of Newton concerning the constancy of velocity of a body in the absence of any extraneous force acting on it, and concerning the equality of the magnitude and opposition of direction of action and reaction, also enter into aspects of chemical engineering work: for example in the relative movement of solids and fluids and in the theory of structures and strength of materials. In applying Newton's laws it is imperative to consider *all* the forces acting on a given element of material in order to obtain a sound analysis of a given situation.

Conservation of atoms

The principle of conservation of mass is a physical one and another similar principle is required by the chemical engineer in considering non-nuclear reactions—namely that of the conservation of atoms. This is, in fact, the basic idea in the atomic theory of matter and forms the basis for expressing the result of any chemical change in which the relative arrangement of atoms among themselves takes place.

This rearrangement differs in degree from one reaction to another. If we accept the statement that certain apparently stable associations of atoms exist which are called molecules, then matter generally is either atomic or molecular, or mixtures of the two types either separately or together. Only in what are called the inert gases such as helium, neon, argon and krypton do atoms exist permanently in comparative isolation at ordinary temperatures. In most of the other 85 or so stable atomic types (elements) known, the atoms of a given element are either closely associated as molecules, in pairs (*e.g.* hydrogen, oxygen, nitrogen, fluorine, chlorine, bromine gases) or in much larger numbers—in the liquid or solid state.

Molecules containing more than one type of atom and containing several atoms, may have the same composition as regards numbers and types of atom but may have different arrangements of the atoms relative to one another. The change from one arrangement to another within the same gross molecular composition is in many instances a 'mild' chemical reaction (*cf.* isomerisation). It is, of course, possible to have an elementary substance in two forms—according to the arrangement of the atoms of the same element relative to one another. The change from one type (of solid) to another of this nature is considered a physical change, *e.g.* rhombic sulphur to monoclinic sulphur.

Valency

In considering the general nature of the association of atoms of different kinds to form molecules, the idea of valency, or combining power, is essential and this varies from zero to eight when expressed in terms of the number of atoms of hydrogen with which one atom of another element may combine. This does not mean that all the hydrides exist or can be made, but that, say, oxides (in which the valency of oxygen is two) or fluorides (univalent fluorine) exist in which the combining powers of the elements are as though they were able to combine with up to eight atoms of hydrogen per atom of element. The elements when arranged in order of increasing atomic weight (more or less) fall into seven periods. These are shown in accompanying table, to which new members (with numbers in excess of 100) are being added from time to time.

It will be seen that vertical divisions into nine group numbers, the first seven being subdivided into 'A' and 'B' subgroups, are also made. This grouping may be used as a rough guide to the valency of an element and for groups O to V inclusive it can be assumed that the element will, in one form, exhibit the valency equal to the group number. For groups VI and VII the only general statement is that the valency of one form of the element is 'group number subtracted from eight'. In the second to sixth inclusive, the valencies range from 0 to 7 and reach 8 near the end of period 6.

The periods one to six contain 2, 8, 8, 18, 18 and 32 elements respectively. One element may exhibit more than one characteristic combining power—depending upon which other elements it is in combination with. For instance, copper, which is element number 29, and lies in group 1 of period 4, exhibits readily both mono and bi valence, and chlorine (element number 17 lying in group VII of period 3) exhibits valencies ranging from one to seven.

The detailed nature of the elements and their compounds lie beyond the scope of these articles and is dealt with in standard works on general chemistry. But the foregoing gives the general basis of stoichiometry (measurement of fundamental parts) which must be observed whenever chemical transformations occur.

Fundamental particles

A deeper understanding of the nature of atoms and chemical reactions depends upon the concept of the atoms being composed of more fundamental particles, among which the better known are neutrons (no electrical charge, mass $\simeq$ hydrogen atom), protons (unit positive charge, mass $\simeq$ hydrogen atom) and electrons (unit negative charge, mass $\simeq \frac{1}{1,800}$ of hydrogen atom), themselves associated in various numbers but in similar proportions in the atoms of the various elements. The elements occurring naturally and with atomic numbers less than 84 are not appreciably radioactive, but the higher numbered elements are, and spontaneously give off alpha (α) particles (helium nucleii doubly charged), beta (β) particles (electrons) and gamma (γ) rays (wavelengths shorter than X-rays). The emission of each α particle from a given atom reduces the atomic number by two, and that of each β particle increases the atomic number by one. Thus one element transforms into another as the result of natural radioactivity. Naturally stable or metastable atoms may be rendered unstable by the injection of neutrons into their nuclei.

The protrons and neutrons together form the nucleus of the atom. The atomic number of an element denotes the number of protons in that element's nucleus. The atomic number of an element similarly denoted the number of electrons distributed at an appreciable distance (in terms of electrons) from the nucleus. Chemical activity of an element is associated with those electrons which may loosely be regarded as 'furthest' from the nucleus. Sets of electrons which number 2, 10, 18, 36 and 54 are particularly stable and the general tendency in chemical reactions is for the participating atoms to loan, borrow or share electrons so that the total number of electrons associated with each atom tends to the number in the stable sets which is nearer to the particular atom's atomic number. This tendency is limited as a rule to an atom:

(1) Parting with not more than four electrons (*e.g.* groups I to IV inclusive)—forming ions;
(2) Taking up not more than four electrons (groups IV to VIII inclusive) which are usually shared with another atom.

The nature of the resulting compounds depends upon the nature of the chemical bonds between the atoms

Group		I	II	III	IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII	O
Sub-group		A	A	A	A	A	A	A				B	B	B	B	B	B	B	
Period	1	1 H																1 H	2 He
	2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
	3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 A
	4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
	5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
	6	55 Cs	56 Ba	57* La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
	7	87 Fr	88 Ra	89 Ac†															

*Lanthanide series	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu

†Actinide series	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 E	100 Fm	101 Mv	102 No

Periodic table

concerned, which may be loosely divided into two categories. Electrovalent bonds are those in which a few electrons per atom tend to be transferred completely from one kind of atom to another kind (from metal to non-metal, say). The compounds known as electrolytes fall into this class and, as the name suggests, they split into charged particles (ions), either when dissolved in substances like water, liquid sulphur dioxide, liquid ammonia or liquid hydrogen fluoride, or when in the crystalline state. Many corrosion problems associated with metallic materials of construction arise from the formation of such bonds. Covalent bonds are those in which pairs of electrons are shared by the atoms combining in such a way that each atom may be regarded as contributing one electron to each pair. Oxygen-oxygen bonds in the oxygen molecule or hydrogen-nitrogen bonds in the ammonia molecule are of this type.

Co-ordinate bonds

Co-ordinate bonds are those in which one atom appears to ' lend ' one or more pairs of electrons to another atom, but does not give up the electrons in the ' electrovalent sense ' and, in fact, the resultant bond is difficult to differentiate from the covalent bond in its nature. Nitrogen in ammonium salts and one sulphur-oxygen bond in sulphuric acid are examples.

It will have been noticed that the most stable numbers of electrons are all even. This is explained by the pairing off of electrons having their energies accounted for by exactly the same set of parameters, except that of spin about each electron's own axis. A pair of shared electrons in a compound, differing only by their direction of spin, are considered to form a covalent bond.

Generally speaking, reactions between elements of which the atomic numbers are not close to that of an inert gas tend to give rise to covalent (or normal co-ordinate) bonds. There are, however, tendencies for certain types of ' hybrid ' bonds to form, which, while mainly covalent, are somewhat polarised electrically. The compounds containing bonds of such a nature have a stronger tendency to associate with one another than compounds of similar molecular weight but with no polar covalent bonds. Water, hydrogen fluoride and alcohols are examples. Such substances, when mixed with ' non-polar ' substances, behave in such a way as to modify the simple laws of physical chemistry concerning what are called ' colligative properties ', *e.g.* total vapour pressure.

For chemical engineering purposes the periodic table may be regarded as a useful summary of combining powers, atomic weights and a pointer to similarities of chemical properties (within a subgroup).

Gas laws

In practice the application of principles of conservation of mass and of atoms is facilitated in some cases by the use of subsidiary laws—especially where gases are involved. Indeed the behaviour of gases has thrown much light on the nature of their composition and on the nature of chemical reaction. The general gas law states that for m g. mol. of gas the pressure p (atm.) and volume V (l.) are related to temperature T (° Kelvin), $pV = 0.082\,mT$. This is more nearly true at low pressures and high temperatures.

Dalton's law states that the total pressure of a mixture of gases or vapours is equal to the sum of the pressures they would each exert individually at the given temperature and number density (*i.e.* molecules of substance A per unit volume). This again is more nearly true at high temperatures and low pressures. It is important in steam distillation.

Avogadro's hypothesis states that equal volumes of gases at the same temperatures and pressure contain equal numbers of molecules. This hypothesis and its various corollaries are of importance in the steam distillation and gaseous reactions. Both ' laws ' are aspects of the general gas law.

If P is the total pressure of a mixture of gases A, B, C

$$P = P_A + P_B + P_C \ldots.$$

$$= \frac{0.082T}{V}(m_A + m_B + m_C \ldots.)$$

is Dalton's law, and

$$m_A = \frac{0.082T}{pV} = m_B$$

is Avogadro's hypothesis.

Thus the analysis of a gas mixture on a volume basis (in which each constituent percentage volume is tacitly referred to at 1 atm. pressure and a fixed common temperature) is also the analysis of the molecular proportions of the constituent species.

Orsat apparatus

Such analyses are important in estimating the efficiency of the performance of a furnace, and may be carried out in a piece of apparatus as devised by Orsat (see diagram), in which a measured volume of the gas is subject to the exhaustive action of (1) potash solution, (2) pyrogallol solution and (3) ammoniacal cuprous chloride solution, in that order. The changes in volume brought about by these reagents lead to estimates of the % CO_2, % O_2 and % CO (by volume) respectively.

The application of the conservation principles and gas analyses to a furnace will now be considered. In continuous processes a situation is usually fairly quickly established where the amount of material in the plant remains constant, thus resulting in equality of mass rates of flow into and out of the unit.

A simple example is that of a continuously oil-fired furnace where the basic changes may be represented as:

Air + oil → flue gases

A common problem in this connection is the evaluation of the ratio of mass flows of air to that of oil from a knowledge of the flue gas composition (usually reported as percentage by volume, on a dry basis) and the fuel composition. The basis of the calculation is (1) the equality of total mass inflow and outflow and (2) the equality of mass flows of atomic constituents into and out of the furnace, *e.g.*

(*a*) The nitrogen fed in the air is the same in amount as that in flue gas for a purely hydrocarbon fuel and negligible nitrogen oxide formation;

(*b*) The carbon fed as oil is the same as the amount of carbon present as CO_2 and CO in the flue gases.

In the simple case in which there is no carbon monoxide in the flue gas, it is obvious that the mass ratio of nitrogen to carbon dioxide is a measure of the mass ratio of air to fuel. To see how to obtain the latter from the analysis of the flue gas when a hydrocarbon fuel is used, let us consider a fuel composed of M% carbon and N% hydrogen on a mass (usually termed weight) basis; 1 lb. of fuel will considered. Taking atomic weights for carbon and hydrogen as 12 and 1 respectively, we have in 1 lb. of fuel

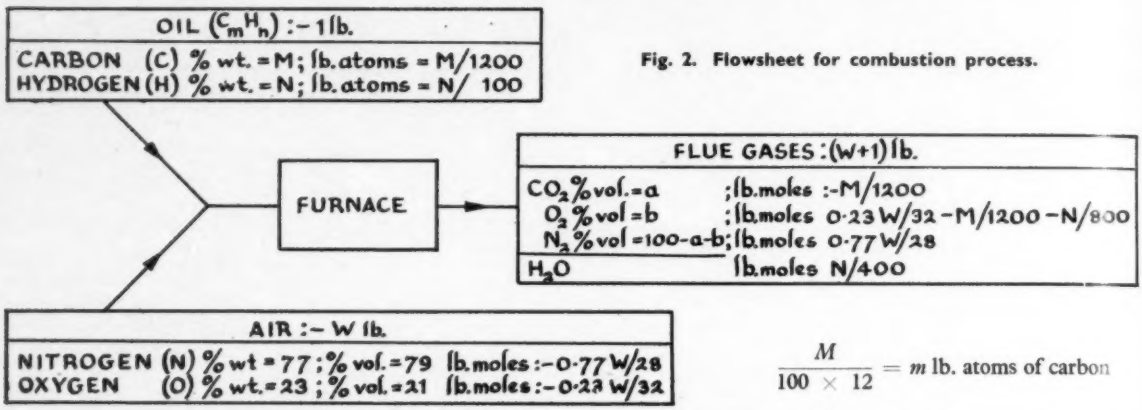

OIL (C_mH_n) :- 1 lb.
CARBON (C) % wt. = M; lb. atoms = M/1200
HYDROGEN (H) % wt. = N; lb. atoms = N/100
FURNACE
FLUE GASES : (W+1) lb.
CO_2 % vol. = a ; lb. moles :- M/1200
O_2 % vol = b ; lb. moles 0·23 W/32 - M/1200 - N/800
N_2 % vol = 100-a-b ; lb. moles 0·77 W/28
H_2O lb. moles N/400
AIR :- W lb.
NITROGEN (N) % wt = 77 ; % vol. = 79 lb. moles :- 0·77 W/28
OXYGEN (O) % wt. = 23 ; % vol. = 21 lb. moles :- 0·23 W/32

Fig. 2. Flowsheet for combustion process.

$$\frac{M}{100 \times 12} = m \text{ lb. atoms of carbon}$$

$$\frac{N}{100 \times 1} = n \text{ lb. atoms of hydrogen}$$

One lb. of fuel can be represented as C_mH_n, and ideal combustion would proceed according to the chemical reaction

$$\left[m + \left(\frac{n}{4}\right)\right] O_2 + C_mH_n$$

$$= mCO_2 + \frac{n}{2} H_2O$$

Taking 32 as the molecular weight of oxygen and 23% as the proportion of oxygen by weight in air, we have the theoretical air/fuel ratio (weight)

$$= \left(m + \frac{n}{4}\right) \times 32 \times \frac{100}{23} \text{ to } 1$$

Now let r = ratio of volume % N_2 to volume % CO_2 in flue gas analysis (in which water has been eliminated), then taking 28 as the molecular weight of nitrogen and 44 as that of CO_2, the weight ratio of nitrogen to carbon dioxide in the flue gas will be $r \times \frac{28}{44}$ while the weight ratio of nitrogen to carbon would be $r \times \frac{28}{12}$, since the ratio of volumes is as the ratio of molecules, and one molecule of CO_2 contains one atom of carbon.

Now, since nitrogen constitutes 77% weight of air and carbon constitutes M% weight of the fuel, then

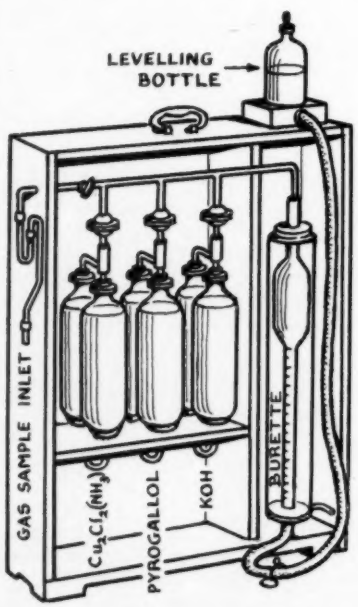


Fig. 1. Orsat apparatus.

the actual air to fuel weight ratio is given by

$$r \times \frac{28}{77/100} \div \frac{12}{M/100}$$

or

$$r \times \frac{28}{12} \times \frac{M}{77}$$

If M is known and r has been calculated from the flue gas analysis, then the actual air/fuel weight ratio $r \times \frac{28}{12} \times \frac{M}{77}$ may be compared with the theoretical value

$$\left[m + \left(\frac{n}{4}\right) \times 32 \times \frac{100}{23}\right]$$

or

$$\frac{M}{100 \times 12} + \frac{N}{100 \times 4} \times 32 \times \frac{100}{23}$$

Alternative route

However, in this simple case, further scrutiny of the flue gas analysis would enable the values of M (= %C) and N (= %H) to be calculated for the fuel from a knowledge of the molecular composition of air (21 O_2 to 79 N_2), and the ratio of the observed oxygen (both as CO_2 and O_2) to nitrogen in the flue gas. The difference in these two ratios is a measure of the amount of oxygen removed as water.

Let the dry flue gas have the analysis:

$$\begin{aligned} \%\ \text{vol. } CO_2 &= a \\ \%\ \text{vol. } O_2 &= b \\ \%\ \text{vol. } N_2 &= (100 - a - b) \end{aligned}$$

Note that $\frac{(100 - a - b)}{a} = r$ of the previous consideration.

Now for $(100 - a - b)$ moles of nitrogen there would originally have been $\frac{21}{79\ (100 - a - b)}$ moles of oxygen. In fact, there are $(a + b)$ moles of oxygen, either combined as CO_2 or free as O_2, in the flue gas, associated with this amount of nitrogen.

The amount of oxygen (moles) consumed by water formation is thus $\frac{21}{79\ (100 - a - b) - (a + b)}$ for the corresponding amount a g. atoms of carbon.

Since for each mole of oxygen consumed in water formation, four atoms of hydrogen are used, we see then

$$\frac{m}{n} = \frac{\text{atoms carbon/lb. fuel}}{\text{atoms hydrogen/lb. fuel}} = \frac{a}{4[21/79\ (100 - a - b -) - (a + b)]}$$

and

$$\frac{M}{N} = \frac{m \times 12}{n \times 1} = \frac{12a}{4[21/79\ (100 - a - b) - (a + b)]} = \frac{M}{(100 - M)}$$

Conclusion

The above are merely illustrations of the stoichiometrical principles that have to be observed. As bases for furnace calculations they are valid provided only carbon and hydrogen are in the fuel and the analysis is reported on dry flue gas. Thus any method of flue gas analysis involving the presence of liquid water must be calculated so as to allow for the contribution of water vapour to the total apparent volume of the gas sample, and for the solubility effects. These are beyond the scope of the present article and should be studied in a volume on the analysis of gases.

INDUSTRIAL PUBLICATIONS

Rare earths. Recent research into the application of ion-exchange techniques to the separation of rare earths has made them available in large quantities, in various grades of purity and at a lower cost than hitherto.

A publication, issued by Johnson Matthey & Co. Ltd., describes the properties, characteristics and availability of rare earth metals, all 14 naturally occurring lanthanons, and scandium and yttrium.

Silicon rectifiers. In a report by Texas Instruments Ltd. on the design features of circuits using silicon rectifiers, the more common single- and three-phase rectifiers are described. Design procedures are discussed for circuits using capacitor-input and choke-input filter sections. Worked examples are given and attention is drawn to the precautions necessary to avoid misuse of silicon rectifiers. Graphs used in the design procedures are collated at the end.

Heat exchangers. The Crane condenser process was developed so that the tubes of conventional straight-tube heat exchangers might be secured and effectively sealed off in their tube plates, while still allowing them freedom to move axially, without deformation or damage to the tube ends. The process is fully described and illustrated in a new booklet, copies available from Crane Packing Ltd.

Nickel alloys. A new publication describes the properties of the high-nickel alloys used in the construction of plant handling caustic soda. Extensive data, giving comparative corrosion rates from a large number of both laboratory and plant tests, form a useful guide in the selection of the best grade of material. Copies are available from Henry Wiggin & Co. Ltd., Thames House, Millbank, London, S.W.1.

Welding fittings. A catalogue (No. 599) on *Tubend* welding fittings, stainless-steel fittings and aluminium fittings is available from B.K.L. Alloys Ltd. The catalogue lists all standard and many special-purpose welding fittings, including elbows, returns, tees, reducers and caps. Also included are specifications for carbon steel and ferretic alloy materials, permissible raw materials for wrought austenitic stainless-steel welding fittings and materials, wrought aluminium alloys, and selected ASTM specifications for low-temperature service.

Natural rubber. Recent work at the British Rubber Producers' Research Association has extended the temperature range at which natural rubber will perform effectively and brought many new applications within its scope. Bulletin No. 4, 'Compounding Natural Rubber for Service at Low Temperatures', explains how, by the use of plasticisers and by chemical modification of the rubber, the lower limit for effective utilisation can be brought down to at least −60°C.

Silicone fluids. A booklet describing the engineering applications of their range of silicone fluids has been issued by Midland Silicones Ltd. The booklet emphasises silicone fluids have high thermal stability and resistance to oxidation, show a remarkably small change in viscosity with temperature and resist breakdown due to shear. They are water repellent and retain good dielectric characteristics over a wide range of temperatures and frequencies.

Increasing Use and Production of Sodium Metal

From our American Correspondent

TOTAL annual production of sodium metal was estimated recently at more than 250 million lb. Due to expansion of facilities this is expected to rise to at least 320 million lb. This is not a sudden rise, but a continuous increase, as can be seen from Table 1.

Table 1. World Sodium Production (in tons p.a.)

	1939	1952
From sodium chloride:		
United States ..	7,300	120,000
Germany	5,200	8,000
Switzerland	500	—
France	—	2,000
England	—	3,000
	13,000	133,000
From sodium hydroxide		
Germany	4,800	2,500
England	4,000	—
Norway	500	500
France	700	1,000
Switzerland	500	500
Japan	1,500	2,500
	12,000	7,000
Total	25,000	140,000

Sodium metal was discovered by Sir Humphrey Davy in 1807. It was largely a laboratory curiosity until Oersted found in 1824 that it reduced aluminium chloride to give pure aluminium. Increasing demand and production have made sodium the cheapest non-ferrous metal. Its price has dropped from $2.00/lb. in 1890 to about 17 to 28 cents today (a few years ago the price was still cheaper).

Sodium, a soft, waxy, silver-white, lustrous metal, is extremely active and oxidises rapidly in air. It therefore must be kept under an oil such as kerosene.

Because of its high reactivity sodium never occurs in the free state. Sodium salts are found in sea-water, salt lakes, alkaline lakes and mineral springs. Rock salt deposits occur where salt lakes have dried up. Soda (sodium carbonate) and common salt (sodium chloride) have been known from early times.

In recent years procedures and equipment have been developed that make sodium metal no more dangerous to handle than many other bulk industrial materials.

Manufacturers of sodium metal

The *Downs* process (electrolysis of the fused chloride) for manufacturing sodium metal is now predominant in the U.S., while the *Castner* process (electrolysis of the fused hydroxide) is more widely used in Germany and Britain.

The largest producer in the U.S. is the Ethyl Corporation, which accounts for a little more than half of the sodium produced, but consumes a large part of it in its tetra-ethyl lead manufacture. Its plants are in Baton Rouge (Louisiana) and Houston (Texas).

Another major producer is E. I. du Pont de Nemours & Co., which also uses most of its own sodium output for anti-knock compounds. Its plants are in Niagara Falls, New York and a new one in Antioch (California).

The United States Industrial Chemical Co. (U.S.I.), a division of the National Distillers Product Corp., is the smallest of the three producers, but it makes most sodium available to the open market. Its plant is situated in Ashtabula (Ohio).

Users of large quantities of sodium find it economical to receive the metal in tank cars containing 40,000 or 80,000 lb. These cars are equipped with channels on the outside of the tank shell to permit circulation of heating oil. Prior to shipment, the molten sodium is solidified. On arrival at the customer's unloading facilities, it is liquefied by pumping hot oil through the channels and blanketed with nitrogen. It is then sucked from the car into storage or weigh tanks by vacuum.

The use of sodium in molten form is most advantageous because: (1) It is introduced in a very reactive form; (2) the rate of addition may be accurately controlled by a valve; (3) the molten sodium can be dispersed readily upon addition to the reaction mass; and (4) the hazards involved are relatively slight, as it is handled under oil or nitrogen in metal equipment.

Industrial applications

Sodium in smaller amounts is delivered in the form of bricks weighing 1, 2½, 5, 12 and 24 lb. each. They are packed in steel drums containing 280 to 300 lb. of sodium. Sodium metal conducts heat and electricity particularly well. It is a very good heat-transfer medium. For this reason sodium-filled valves in aircraft engines are much used nowadays. The hollow head and stem of the valves are filled with sodium and then sealed. The valves are not warped at very high temperatures because of sodium's excellent heat conductivity.

The main use of sodium metal, however, is in the preparation of anti-knock compounds for petrol. Other traditional uses are in the manufacture of detergents, bleaches for pulp and paper, wetting agents, pharmaceuticals, barbiturates, insecticides and plastics. In metallurgy, sodium is used to remove the scale formed during the hot processing of stainless steels and other alloys, in the manufacture of

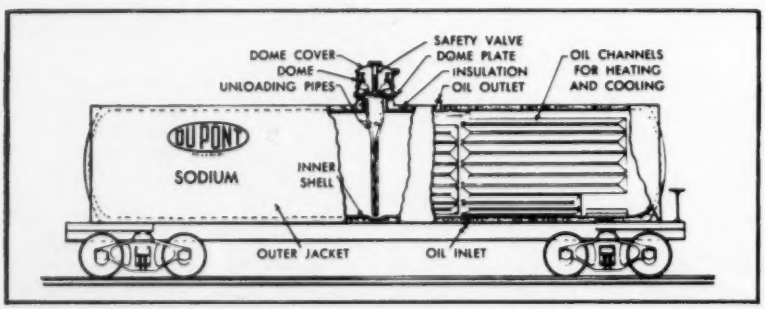


Fig. 1. Melted sodium is piped into a tankcar where it solidifies on cooling. At its destination it is liquefied for unloading. The cross-section of the interior of a tankcar shows oil channels for heating and cooling.

titanium metal, in deoxidising brass and copper, in preparing special lead cable sheathing, in hardening bearings, etc.

Sodium as a conductor of electricity is exceeded only by silver, copper, aluminium and gold. Sodium vapour is used to make highway lights more penetrating in foggy areas.

Nuclear power stations

Three interesting new applications are in use. Firstly the use of the metal in liquid form to remove heat from nuclear reactors for production of steam for electric power generators. Sodium has the following advantages over water in nuclear reactors:

(1) Very high film heat-transfer coefficient.
(2) Greater permissible temperature rise of coolant without involving pressure.
(3) Sodium does not corrode stainless steel.
(4) Removal of larger amounts of heat from the fuel elements.

Nuclear energy plants in California, Idaho, Michigan, Nebraska and Alaska, having together a capacity of 575,000 kw., now in the planning or construction stage, will use sodium.

It is estimated that 10% of the new power plants built by this year will be nuclear and that 50% of the new plants built by the year 2000 will use nuclear fuel rather than fossil fuel or hydro-electricity. One can thus arrive at sodium requirements of 750,000 lb. by 1960 and 315 million lb. by the year 2000, assuming 100% of the nuclear capacity to be sodium-cooled.

The second largest potential market for sodium is as a reducing agent in making titanium and zirconium. The Electro Metallurgical Co. is turning out 15 million lb. of titanium p.a., using 30 million lb. of sodium. U.S.I. plans to make 10 million lb. of titanium p.a. at Ashtabula also, and is building a plant there to make 2 million lb. p.a. of zirconium, a structural metal for nuclear reactors. This would use some 20 million lb. of sodium.

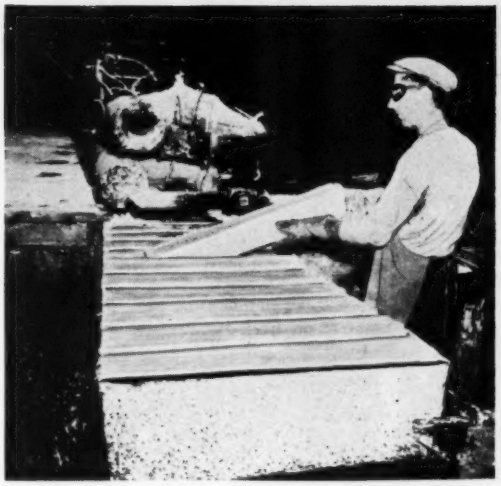


Fig. 2. Liquid sodium is run into moulds. The picture shows the bricks being removed at the Du Pont factory, Wilmington.

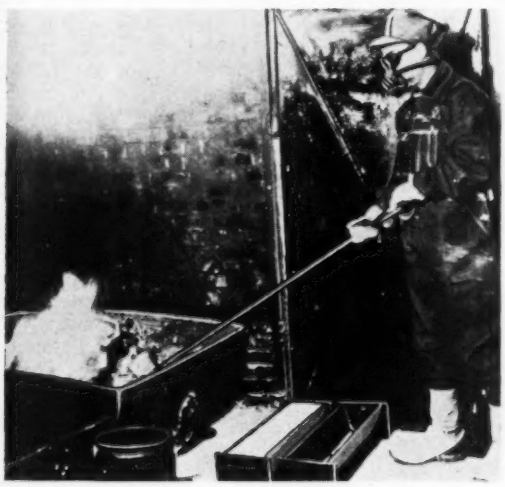


Fig. 3. This photograph shows a typical method of disposing of sodium residues—by burning at the Du Pont factory in Wilmington, Delaware.

Some newer titanium companies are convinced that the sodium processes have certain advantages from an economy standpoint over the magnesium reduction method used by longer-established titanium manufacturers.

High-energy boron fuels

The third new application for sodium is as a chemical intermediate in the synthesis of high-energy boron fuels for rockets, guided missiles and other aircraft. In such a continuous process, a high-density boron product is prepared by spraying molten sodium into the boron trifluoride gas at temperatures above 1,000°C. and preferably above 1,500°C. Developments in this field are naturally secret, but sufficient information has been divulged to raise the hopes of American sodium manufacturers.

Ion accelerator and multichannel analyser

It was recently announced that the U.S. Atomic Energy Commission has awarded Columbia University $44,200 to expand its nuclear science and engineering programme. These funds will be used to purchase an ion accelerator and a multichannel analyser for experiments with the water-moderated and graphite-moderated 'sub-critical' atomic reactors now in operation on the Columbia campus. The reactors were built last year with a $76,000 grant from the A.E.C.

In addition, a device called a creep and relaxation testing machine will be purchased under the new grant. The machine is used to study the stretching of metal under high temperatures.

The accelerator will produce deuterium ions and accelerate them under high voltage. They will then collide with other deuterium nuclei, and break apart to produce neutrons. This operation can be carried out in frequent short pulses, and the accelerator is thus a 'pulsed neutron source.' These neutrons will be released into water or graphite, with or without uranium being present.

The multichannel analyser will be 'triggered' by the accelerator and will count the neutrons to record how many neutrons are present at various locations during specified time intervals after each pulse.

Canadian Waste Disposal Technique

By J. Grindrod

With the growing rate of urbanisation and industrialisation the problem of efficient waste disposal is becoming acute. A novel technique suitable for a variety of processes such as municipal sewage sludge and waste pulp slurry treatment has been recently developed in Canada. Trials were carried out both in the laboratory and at selected points in the country. A measure of its success is the fact that the Atomised Suspension Technique has been fully accepted by the Health Department of Quebec Province.

A NEW process, known as the atomised suspension technique (AST), has been evolved in Canada and is believed to have a vast potential in the field of waste disposal.

Invented in 1953 by Dr. W. H. Gauvin, head of the chemical engineering division of the Pulp and Paper Research Institute of Canada, this process is a method of effecting thermal separation of dissolved or suspended solids from liquids and is applicable to the treatment of many types of solutions and slurries in a wide range of processes, though so far it has been used mainly for the treatment of sewage sludge.

Apart from its use in waste disposal and against water pollution, the process has been proved, at least experimentally, to be applicable to a variety of processes ranging from the roasting of sulphide ores to pulp-mill liquor recovery. Some of the applications which have so far been studied are the treatment of municipal sewage sludge, pulp-mill spent liquors (chemical recovery in alkaline, acid and neutral sulphite semi-chemical pulping processes), destruction of a variety of waste slurries in the pulp and paper and chemical processing industries, processing of metallic ores, treatment of pickling liquors from steel mills, oxidation of wastes from a meat-packing plant, oxidation of tannery wastes, treatment of pharmaceutical wastes, conversion of distillery wastes to cattle feed and treatment of wastes from the food and canning industries.

Patents have been granted to the Canadian Pulp and Paper Research Institute in respect of the process in Canada, the U.S.A. and seven other countries and patents are pending in six other countries.

Procedure

Essentially, the method consists of spraying the solution or slurry to be treated through an atomising nozzle into a heated reactor and, within the reactor, effecting a series of physical and chemical transformations in a continuous operation. Initial thermal separation of the solids by evaporation might be followed by chemical treatment of the solids in several phases at fairly high speed.

The purpose of such pre-evaporation is to reduce the evaporation load on the reactor by increasing the solids concentration of the feed and this can be done by utilising the waste gases from the reactor jacket or from within the reactor. Normally, the degree of pre-evaporation required would be the amount giving the feed sufficient total B.Th.U. value to make the unit thermally self-sufficient through the burning of combustible gases or solids produced within the reactor. A difficulty might be, however, that the pre-evaporated feed at the required consistency might become viscous and difficult to pump and atomise.

Reactor

With the required consistency of the feed having been achieved, the solution is sprayed through an atomising nozzle in the head of the reactor, the walls of which are maintained at the required temperature (in the case of sewage sludge treatment around 1,400°F.). At the start-up, this temperature would be achieved by external means such as by gases from a furnace, oil or electricity. Later, when the combustibles recovered from the process can maintain the required heat, the external source can be discontinued.

Normally the walls are hottest in the upper part of the reactor to handle the heavy evaporation load and the heat diminishes throughout the reactor. Where a series of reactions are required, however, it may be desirable to have zones of various heat intensity. With electric heating, this provides no great problem. No air or gases (other than small quantities required for atomisation where a pneumatic nozzle is used) are introduced at the head of the reactor. Hence there is no gas film surrounding the droplets produced by atomisation, so that the rate of heat transfer is high and evaporation very rapid. The droplets become suspended in the vapour produced in the evaporation zone and this is the atomised suspension.

In the spray pattern, the droplets do not intersect the hot reactor walls before reaching their terminal velocity. Having reached this, however, they are repelled from the wall both by the large thermal gradient next to the wall and by the violence of their own evaporation on the side nearest the wall. This repulsion prevents scaling and corrosion of the reactor wall. The violence of the evaporation, however, causes deep pits and cracks to appear on the surface of the particles, thus increasing the effective surface area of the particle and thereby increasing the heat-transfer efficiency.

As the suspension moves down the reactor, the droplets become semi-solid particles and enter a drying zone where the internal moisture of the particles diffuses to their surfaces and is evaporated. At the end of the drying zone, physical separation of the solids in the feed has been achieved.

Some further treatment of the dried solids, for example, continued tem-

perature increase, may be necessary. Then particles of an organic nature, such as sewage sludges, would undergo pyrolysis, evolving gases such as methane, carbon monoxide and carbon dioxide and their carbon content would greatly increase. With continued pyrolysis, reactions between the gases and the carbon might reduce the carbon content of the particles. Since the pyrolysis of organic material is an exothermic reaction, the reactor wall need not be maintained at extremely high temperature in this zone.

Reactions, or a series of reactions, other than pyrolysis may be accomplished without decreasing the efficiency of the system, thanks to the absence of longitudinal mixing within the reactor. For example, air may be introduced after the drying zone which will oxidise the organic solids in domestic sewage, rendering them inert. This would not, however, interfere with the high heat-transfer efficiency of the upper zone which is due to the absence of this foreign gas.

Treatment of solids

Solids from the reactor may be extracted from the vapour stream in a cyclone separator, if necessary, followed by a scrubber. The solids may have commercial value, *e.g.*, sewage solids may provide a useful fertiliser or soil conditioner.

If operated under high pressure, the dirty steam from the reactor may be convered to process steam at a somewhat lower pressure. Where the reactor is operated at atmospheric pressure, the steam may be condensed to provide hot water which might be used for space heating. The gas stream from the reactor might also be used, prior to condensation, within the AST system to pre-heat the feed or the oxidising air to the reactor and provide a credit to the heat balance of the system.

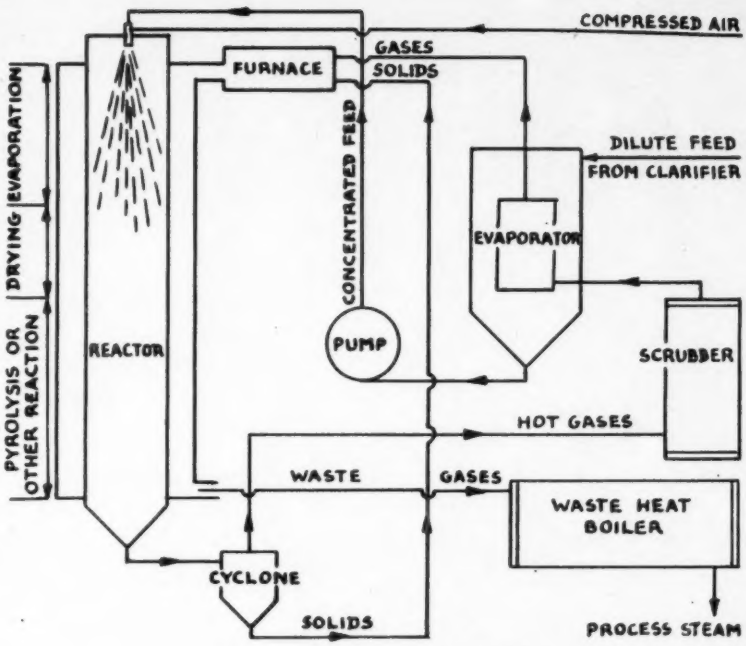


Fig. 1. AST generalised flowsheet.

Combustible gas

Any combustible gases produced in the reactor might be burnt to produce heat for the reactor by burning them in a furnace and the hot flue gases injected into the reactor jacket. To maintain the top reactor zone at about 1,400°F. such gases must enter at about 2,700°F. Frequently they would leave the reactor at fairly high temperatures, and this heat may be recovered by means of a simple waste-heat boiler. Non-combustible, non-condensable gases would be vented to atmosphere at comparatively low temperature.

By the AST technique, all the main operations can be flexibly carried out in a single piece of equipment giving a simple flowsheet. Reaction rates are high and large volumes can be processed in relatively small equipment. No scaling or corrosion occurs if care is taken in design and nozzle selection. Heat efficiency and recovery are good and sometimes thermal self-sufficiency is possible.

In the case of sewage sludge treatment, the plant is compact and its capital cost low and, since it can operate at atmospheric pressure, simple construction is possible. The pyrolysis reaction is strongly exothermic providing considerable excess heat. Thermal self-sufficiency is possible, but sewage sludge does present a handling problem on concentrated feeds. Excellent heat recovery can be obtained, however, by means other than pre-evaporation.

Conclusions

Almost completely automatic operation can be achieved and the unit can be worked on a 24-hr./day basis without constant attention. In the case of sewage sludge disposal, capital costs are claimed to compare favourably with conventional methods. The quoted figures are: up to 5,000 population, $25,000; up to 10,000 population, $45,000. Operating costs are still being compiled but, for an electrically heated unit to serve a 10,000 population town, they are expected to be in the region of $7,500 p.a. For general industrial use, too, the atomised suspension technique appears to offer many technical and cost-saving advantages.

ACKNOWLEDGMENT

The writer is indebted to the National Welding Co., of Montreal, who engineered the prototype plant installed at Beaconsfield, Quebec, for material from which this article has been prepared.

Of interest to our readers . . .

A number of articles appearing in our associate journals this month will appeal to readers of CHEMICAL & PROCESS ENGINEERING.

Manufacturing Chemist—Effluent Treatment in the Insecticide and Weedkiller Industry, by Dr. D. H. Sharp.

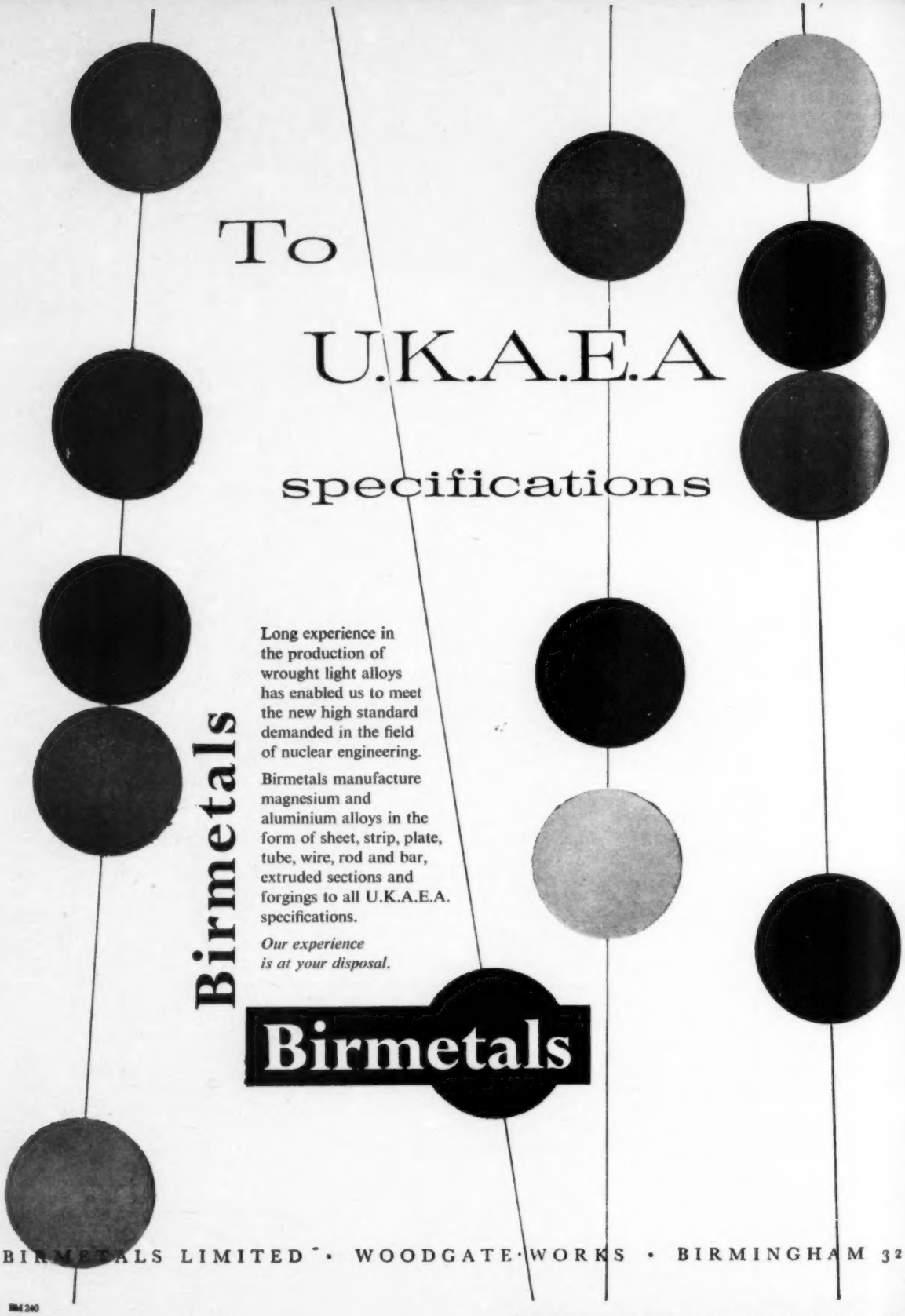
Food Manufacture—Mechanisation of Food Plant, by Leo Walter.

Dairy Engineering—Laying Out In-Place Cleaning Circuits, by C. H. Brissenden.

Petroleum—Tank Truck Design: Theory and Practice, by A. A. E. Calcott (Mobil Oil). Natural Gasoline Recovery: Some Economic Aspects, by P. W. Sherwood.

Paint Manufacture — Carbon Black Pigments, by P. Lowe. Advanced Paint Chemistry, by Dr. P. M. Fisk.

Automation Progress — Polarographic Analysis and Process Control, by Dr. D. C. Munro. Attitudes to Automation in Britain and the U.S.A., by D. B. Foster.



To

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Uranium at Le Bouchet

By F. R. Paulsen
B.Sc., Ph.D., F.R.I.C., F.C.S.

[*Photograph by courtesy of the French Atomic Energy Commission*
Le Bouchet.

This article not only describes the extraction of uranium from French ores, but gives details of some of the similarities and differences to practice in Britain. Figures are given for uranium production and, since this is linked with plutonium production, it is an indirect assessment of France's status as a fourth member of the nuclear club.

FRANCE is the fortunate possessor of extensive uranium deposits which enable the nuclear programme to go forward without dependence upon purchases from overseas. She is, in fact, the largest producer of uranium in western Europe, and the known resources of metropolitan France exceed 50,000 tonnes. Production of 60% concentrates will increase threefold over the 1957 figure by 1961. By 1975 the national usage of electrical power will have reached 200 milliard kwh., 25% of which will be nuclear. This huge expansion will require large amounts of uranium, and the rate of production of this metal has been accelerated to meet the need.

In 1952, M. Felix Gaillard, the then Secretary of State, put forward a five-year plan for nuclear power development, including the production of fissile material, and in 1955 this plan was augmented by Minister G. Palewski. The discovery and exploitation in metropolitan France, and in French territories overseas, of uranium and thorium minerals eventually made France the greatest producer of fissile materials in Western Europe. For the preparation of plutonium, huge piles were built at Marcoule, very similar in type to the British ones at Windscale. A uranium processing plant was established at Le Bouchet—one of the finest and most up to date in Europe. The expansion of this processing centre can be seen from the following figures for the staff employed there:

December	*Personnel*
1951	156
1952	167
1953	228
1954	270
1955	346
1956	366
1957	415

Administration

The exploitation of the mineral resources comes under the control of the Direction des Recherches et Exploitations Minières (D.R.E.M.), which organised aerial surveys and established mines at Grury (Sâone-et-Loire), le Forez, Limousin and Vendée, as well as in Madagascar. The minerals are dressed and concentrated near the actual mine site by physical and chemical methods, until the uranium concentration is sufficient to warrant transport to the final processing plant at Le Bouchet. The 1957 production of 60% concentrates was equivalent to 380 tonnes of metal, and this amount was expected to increase to 500 tonnes in 1958 and to 1,000 tonnes by 1961, with a target of 3,000 tonnes eventually.

At Le Bouchet, uranium makes its first appearance in the metallic form for fabrication into the various types of fuel elements required for power and research reactors. This works was installed in December 1946 in what was formerly the gun-powder factory near Corteil, about 50 km. from Paris. By January 1948 the production of uranium oxide for the Fontenay reactor commenced, and by 1950 metallic ingots were in routine production. By 1957 a new modernised plant was operating at Le Bouchet, and Madagascar uranothorianite was being treated not only for uranium extraction, but also for the thorium salts of nuclear purity. The Bouchet plant at present produces sufficient nuclear fuel to supply all those piles operating on natural uranium at Fontenay, Saclay and Marcoule. It is likely to continue on full production for many years, but must expand in size and capacity to cope with the

requirements of the national programme. At Le Bouchet there is, in addition to production, a considerable bulk of research. Laboratory and semi-plant-scale work is carried out, with a view to improving production methods, so that fuel prices can be further reduced.

Mineral treatment

The various stages in the fabrication of uranium metal from the 60% concentrates are as follows. It will be noted that, in general principles, the process resembles closely that employed at Springfields in the U.K.

The first stage is the conversion of mine concentrates into uranyl nitrate. The uranates, as sodium or magnesium uranate cake, are dissolved in nitric acid. The filtered solution is the feed to the next stage, in which the uranyl nitrate is extracted into an organic solvent. The uranyl nitrate, containing 550 to 400 g./litre, and 1.7N in acid, is fed to the top of a pulsed tower containing specially selected clay. Upwards through this tower passes a mixture of tributyl phosphate (TBP) and white spirit in the proportions 65 : 35.

The aqueous solution emerging from the base of the tower contains only 100 to 200 mg./l. of uranium, but this is recovered as ammonium diuranate, which is returned to the first stage. The proportions of aqueous to organic phases in the tower are 1: 3, and the uranium concentration in the TBP layer leaving the top of the tower is 120 g./l. This organic layer now passes to the next stage, that of re-extraction. The organic phase passes upwards in a tower, while water is sprayed downwards. The water re-extracts the uranium salt and this is removed from the bottom of the tower at a concentration of 60 g./l. and an acidity of 0.5 to 0.6N.

The aqueous phase is now neutralised by ammonia solution, so that the uranium is thrown out of solution as ammonium diuranate, $(NH_4)_2U_2O_7$. This solid is collected and washed on a rotary filter of unusual design, and from this the filtrate contains only about 5 mg./l. of uranium. A horizontal filter-screen is divided into a series of close-fitting sectors and rotates slowly. To the underside, suction is applied. The liquid is applied from above, and it filters through into the chamber beneath. Suppose the grid contains 12 sections. The liquid is applied, say, at position '12 o'clock,' but by the time this sector is at the '11 o'clock' position the cake is dry. The sector rotates about a radius of the screen, so that the cake is thrown into a bin beneath; by the time the sector has reached the '12 o'clock' position again it is back in the horizontal position and ready to receive more liquid. The dried cake contains about 30% of moisture, and its uranium content is about 40%.

The cake passes to a band drier in which there is a temperature gradient from 120°C. to 350 to 400°C. The ammonium diuranate is first dried and then undergoes thermal decomposition with production of uranium trioxide, according to the equation:

$$(NH_4)_2U_2O_7 = 2NH_3 + H_2O + 2UO_3$$

The purity of this trioxide is now about 81.5 to 83.0%.

Conversion to dioxide

The next stage in the process is the conversion of this trioxide to the dioxide, by means of hydrogen:

$$UO_3 + H_2 = UO_2 + H_2O$$

If this is carried out at 600°C., the resulting dioxide is found to be more reactive towards hydrogen fluoride, which is used in the next stage. It is also more reactive to air, and is actually pyrophoric, or liable to spontaneous inflammation in contact with air. To remove this fire hazard, the reduction with hydrogen is carried out at 850 to 900°C.

The trioxide enters a hopper at the top of a vertical electric furnace. As it passes downwards, it encounters a stream of hydrogen and nitrogen produced by the thermal 'cracking' of ammonia gas introduced from below. Reaction with the hydrogen results in the formation of uranium dioxide, which is caught by a horizontal screw conveyor and dumped into a receiver. It now consists of about 88% uranium dioxide, UO_2. This dioxide is delivered to a machine which converts it into uranium tetrafluoride, by a process of hydrofluorination, or reaction with hydrogen fluoride. The latter gas enters at the base, and at a temperature of 500 to 580°C. reacts with the oxide according to the equation:

$$UO_2 + 4HF = UF_4 + 2H_2O$$

The necessity for this stage is based upon the thermodynamic requirements of the formation of uranium from its fluoride, and upon the necessity of obtaining a convenient slag in the reduction stage which is to follow. Uranium trioxide reacts too violently with calcium, while the tetrafluoride is preferable to the dioxide, since the calcium fluoride formed melts readily and can easily be slagged off. The uranium tetrafluoride leaving the hydrofluorination furnace is caught in a horizontal screw conveyor and deposited in a receiver. Now comes the final chemical operation, that of the reduction to the metal itself.

Reduction with calcium

In a stainless-steel cylinder, somewhat more than 1 m. high and about 1 m. in diameter, a special core is placed, the intervening space being packed with powdered fluorspar. Removal of the core leaves a crucible, perforated at the bottom. This per-

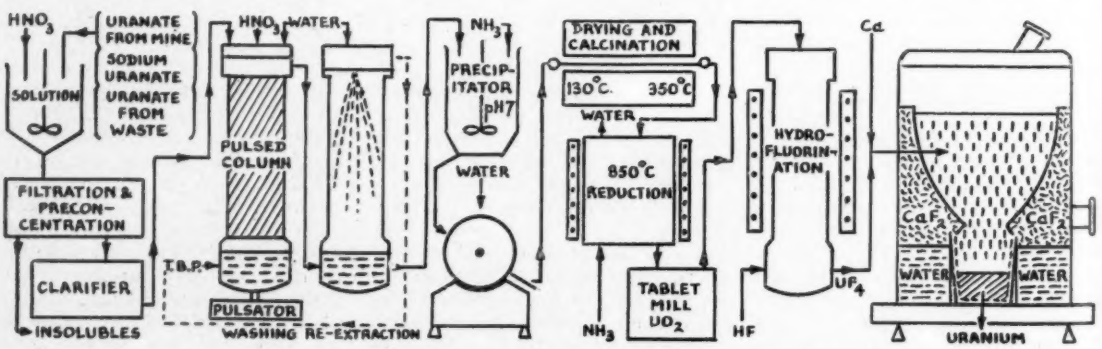


Fig. 1. Diagram of plant and operations used at Le Bouchet.

foration accommodates a stainless-steel crucible fitting snugly into a water-cooled chamber which runs around the wall of the container. Into the stainless-steel crucible is placed an inner crucible. The charge, consisting of an intimate mixture of uranium tetrafluoride and calcium metal, is fed in.

A domed cover is put into place and held in position by a series of spring-loaded clamps. The container is now evacuated. Through a tubulus in the cover a special ignition 'candle' is placed, and the insertion of a plunger

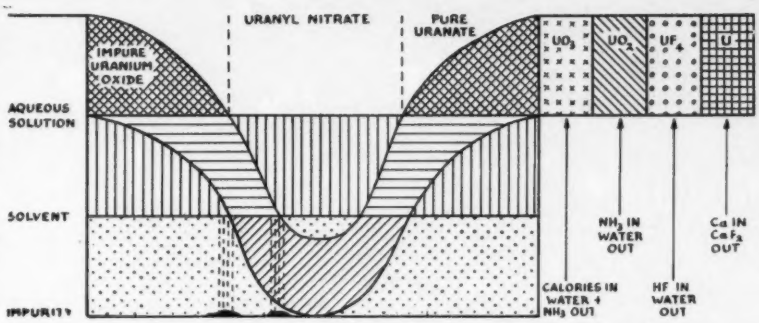
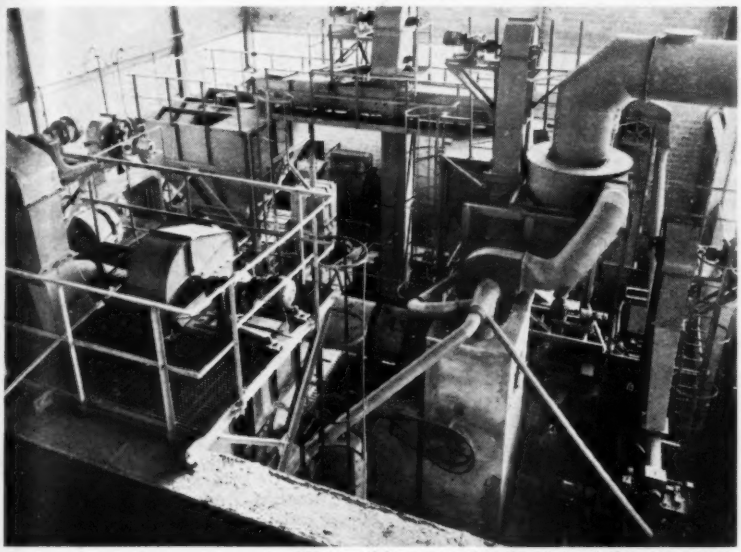


Fig. 2. Diagram of the various chemicals involved in the process at Le Bouchet.



[Photograph by courtesy of the French Atomic Energy Commission

Fig. 3. Ore-grinding plant at Le Bouchet.

sets off the firing charge. This in turn ignites the main charge, and the reaction proceeds rapidly, according to the equation:

$$UF_4 + 2Ca = 2CaF_2 + U$$

The temperature attained is about 1,400 to 1,800°C., and the pressure, as indicated on a gauge, rises rapidly. When the reaction is over the pressure again falls and, as soon as it reaches 600 g./sq.cm., an outlet in the side of the container is opened. Any excess calcium metal escapes and burns with a bright red flame at this outlet. The cover is then removed and the crucible lifted out by means of chains. The uranium metal meanwhile has collected in the crucible, in 98.5% yield. Further uranium can be extracted from the slag.

Although magnesium is cheaper than calcium and less is required for the reduction of a given amount of uranium tetrafluoride, reaction with it is much more difficult to initiate. For this reason calcium is used, although in Britain magnesium is still preferred.

The uranium produced at Le Bouchet is very pure, containing about 50 p.p.m. of iron, 5 p.p.m. copper and 10 p.p.m. nickel. The production of uranium metal at Le Bouchet has increased rapidly, as the following annual tonnages will show:

1952	9
1953	29
1954	67
1955	79
1956	145
1957	285
1958	401

Fig. 1 shows the plant and operations used at Le Bouchet, while Fig. 2 illustrates the various chemicals involved in the processes.

Comparison with U.K.

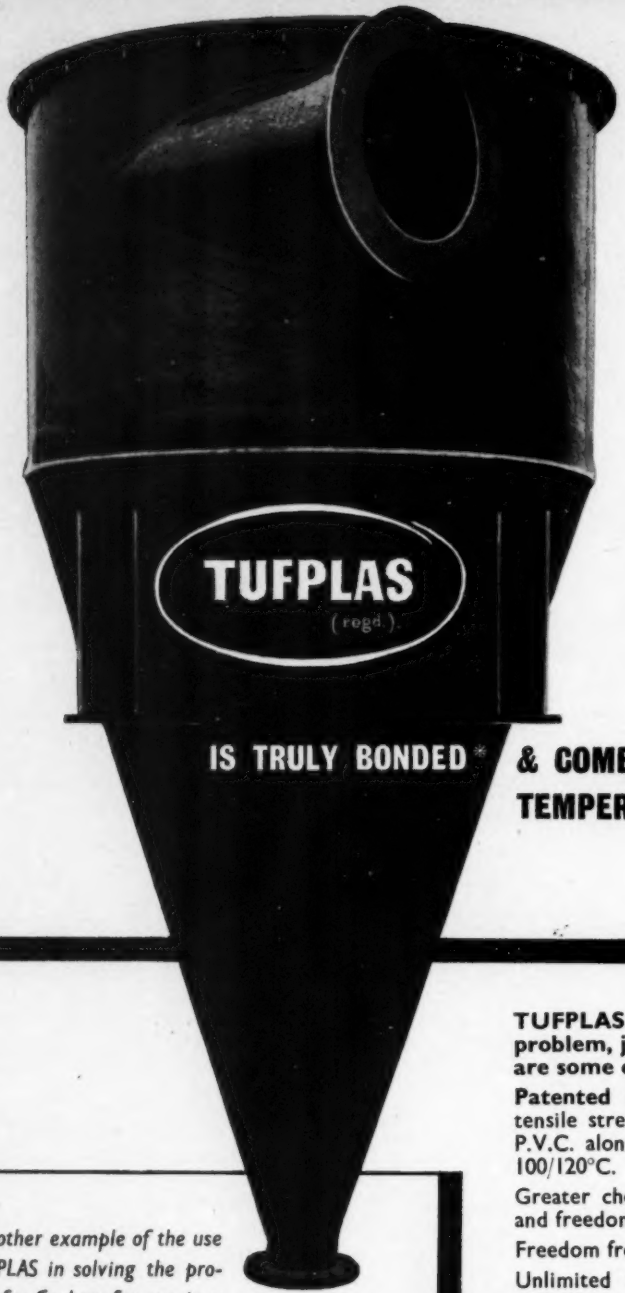
Since there has been the closest possible collaboration between the U.K.A.E.A. and the C.E.A., it is hardly surprising there is a great similarity in the methods used in uranium extraction in France and in Britain. What are the major differences? Firstly, until comparatively recently, Springfields was operating on ores, but now concentrates are used, as in France.

Next, the new Springfields process eliminates the use of ether in the purification of the uranyl nitrate made by dissolving the concentrates in nitric acid, and a TBP process is now employed. France has been using this process for some time. In France this solvent extraction process is carried out in pulsed towers, while mixer-settlers are used at Springfields. The drying of the ammonium diuranate and conversion into uranium trioxide are done by spray-drying in Britain, but in ovens in France. For the next stage, that of reducing the trioxide to dioxide, France uses cracked ammonia, while Britain uses hydrogen.

In the conversion of the uranium tetrafluoride into uranium metal, the British method relies on the reaction with magnesium inside a crucible lined with graphite. The French use reduction of the tetrafluoride with the dearer metal calcium, in a large crucible lined with fluorspar. Further, the furnace charge in this last process is powdered in the case of the French process, but pelletted in Britain. It will be very interesting to see whether, when Springfields adopts the fluidised-bed process for direct conversion of uranyl nitrate to uranium tetrafluoride (a step which will eliminate all ammonium diuranate preparation and decomposition), the French will be tempted to follow suit. At present, it would be impossible to say which country has the more efficient process.

In the article 'French Fuel Element Developments' which appeared in the April issue we published a photograph of SATURNE at Saclay. This was inadvertedly captioned 'reactor'. It should in fact have read 'particle accelerator'—Ed.

CORROSION



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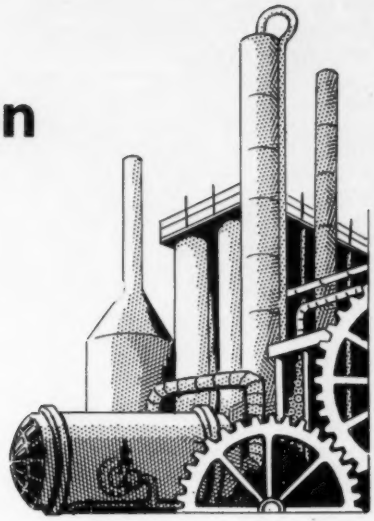
Materials of Construction for Chemical Plant



PVC

By J. A. Rhys,* M.Sc., A.K.C.

We are opening our extensive series on 'Materials of Construction for Chemical Plant' with an article on PVC. Various polymerisation mechanisms for this polymer are described and the physical properties of plasticised and unplasticised PVC are mentioned. An historical account of the use of this material in chemical plant is given and the author concludes with some figures illustrating the increasing use of PVC in the chemical industry.

THE beginning of PVC as a commercially useful material is found in the early thirties,[1, 2] but the development of plasticised PVC in Britain grew very slowly until the second world war, and that of the unplasticised material hardly began. The problems of insolubility and inertness which so troubled the fabricators at that time have now become the properties which are particularly desirable for use in chemical plant. In Germany the advantages of these properties were soon recognised. Applications were developed early in the decade following the patents of Semon,[1] and in 1946 de Bell, Gloor and Goggings[3] reported that 1,200 tons p.a. of rigid PVC were being used in Germany for chemical pipework alone. These and other disclosures after the war excited the interest of other countries. Thus PVC, due to the ease with which it can be fabricated, and due to it being a tough abrasion-resistant material with excellent resistance to chemical attack and to weathering, was seen to have considerable potentialities. These are now being realised. The production of PVC resin in the U.K. has grown from 3,000 tons in 1944 to a little short of 100,000 tons p.a. by 1960.

Production

Vinyl chloride is usually prepared by the catalytic hydrochlorination of acetylene. The single molecules of vinyl chloride are then caused to link up under controlled conditions to form the long-chain molecules or polymer which is the basic PVC resin. This product will have properties which may be varied within quite wide limits depending on the nature of the catalyst used, the presence of modifying agents, the mechanics of the polymerisation reaction, and the conditions of time and temperature.

In addition molecules of vinyl chloride may be mixed with other reactive molecules to produce co-polymers. Co-polymers in commercial production are those formed from vinyl chloride and vinyl acetate, from vinyl chloride and vinylidene chloride, and ter-polymers formed when maleic anhydride is added as a third reactive monomer. In all of these, the vinyl chloride forms the major part of the compound, the other materials being present in amounts varying from 2 to 15%. These co-polymers have properties which differ considerably from the parent homopolymer. They were developed to improve some desirable quality; this was not achieved without sacrifice of some other property.

There are two main methods of production.

(1) Emulsion polymerisation

Commercial emulsion polymerisation involves the use of emulsifiers, activators and modifiers. These can be soaps, peroxy compounds and mercaptans. The final product is in the form of a latex and, in order to obtain the solid polymer from this, it must be spray dried. It therefore contains residual particles of the ingredients used to govern the mechanics of the polymerisation, which will affect certain properties of the polymer. The electrical properties are especially sensitive to traces of these materials, so that emulsion polymers had electrical properties inferior to those of polymers produced by the suspension technique. Optical clarity, too, is not so good.

(2) Suspension polymerisation

In this process the monomer is dispersed in water by stirring with a suspension stabiliser such as talc or bentonite clay. Each monomer globule polymerises as a miniature system and

*F. W. Berk & Co. Ltd.

results in a granule or pearl which, at the end of the process, may be precipitated, washed and removed from the system. The result is a purer polymer with improved properties.

In either case the molecular weight of the polymer can be controlled, and the resultant polymer is usually characterised by its K value. The K value is calculated according to Fikentscher[4] from the measurement of the relative viscosity at 25°C. of a solution of 0.5 g. of the polymer in 100 ml. of ethylene dichloride. It is a measure of the size of the polymer molecule and so, in a given polymer, the higher the K value the greater the processing temperature required to attain the best mechanical properties and the higher the values of these properties.

Thus in considering the suitability of a PVC resin for a given application it is necessary to consider whether:

(*a*) The polymer is a homopolymer or a co-polymer;
(*b*) It has been produced by emulsion or suspension techniques;
(*c*) It has a suitable K value.

High-impact PVC

A recent development is the production of high-impact PVC, known in the U.S.A. as Type II PVC. In that country the polymers described above are known as Type I PVC. High-impact PVC is a mixture of PVC and certain selected synthetic rubbers. This results in a material with considerably increased impact strength, but accompanied by a slight falling off in chemical resistance, and in certain physical properties (see Table 1).

Fume removal fan made from transparent 'Cobex' laminated with expanded metal by Tanks & Linings Ltd.

Before PVC resin can be processed into end-products it must be compounded with other materials to develop or to protect the desired properties. The compounding materials most commonly used are plasticisers, extenders, stabilisers, fillers, lubricants and pigments.

Plasticisers and extenders

Plasticisers and extenders are organic materials, usually esters, which when mixed with the resin convert it from a hard to a softer, more flexible, more workable substance. Usually they are not added in amounts of over 50% of the compound. The amount added will determine the softness of the product, thus enabling the compounder to produce a range of compounds varying from rigid to soft and rubber-like. The plasticiser's main function is to soften and ease the processability; it should also, however, be chemically inert, of low volatility, insolvent, non-toxic and of low flammability. The more commonly used plasticisers are dioctyl phthalate, phthalate of mixed C_7 and C_9 alcohols, tritolyl phosphate, dioctyl and dibutyl sebacates and adipates, polypropylene sebacate and adipate, epoxy esters and nitrile rubbers.

Certain chlorinated compounds can be used to replace part of the plasticiser. These are termed extenders and, when used, reduce plasticiser costs, improve flame resistance, and do not affect the properties of the compound to any great extent.

Stabilisers

PVC is by nature thermally unstable. It decomposes at about 180°C. The temperature range over which PVC can be used may be extended by the addition of small amounts of certain substances termed stabilisers. These retard and minimise the evolution of hydrochloric acid, the main by-product of decomposition. During decomposition the polymer develops colour (yellow — brown — black) and its properties deteriorate. Many of these stabilisers which protect the compound against thermal degradation also protect it from the effects of ultra-violet light. Substances used as stabilisers are lead salts, other heavy metal soaps and organic compounds, organic compounds of tin, and epoxy compounds. In the U.K. about 75% of the PVC resin is stabilised with lead salts.

Fillers, pigments and lubricants

Fillers are used to increase hardness and insulation resistance, and to reduce resilience, shrinkage and cost. Clays, chalk whiting and carbon black are the main fillers used in PVC.

Materials such as stearic acid, metallic stearates and waxes are used to aid processing by overcoming the tendency of the compound when hot to adhere to the processing equipment.

Pigments used in PVC must be stable at processing temperatures (140 to 200°C.) and resistant to hydrochloric acid which may be evolved during the process. Many pigments act as stabilisers because they help to screen the compound from ultra-violet light.

PVC compounds are versatile in processability and in methods of fabrication. These include all the well-known processes.

Table I. Physical properties of rigid PVC.

	Co-polymer	*Homopolymer*	*High-impact grade*
Specific gravity	1.37—1.45	1.38	1.35
Tensile strength, p.s.i.	7,500	8,500	6,000
Flexural strength, p.s.i.	12,000	13,500	12,000
Flexural modulus, p.s.i.	450,000	500,000	450,000
Izod impact strength, ft.lb./in. of notch	0.5	0.8	15
Thermal expansion, in./°C.	0.00007	0.00005	0.00010
Heat distortion, °F. at 264 p.s.i.	145	165	155
Flammability	← Self-extinguishing →		
Thermal conductivity, cal./sq.cm./sec./°C.	0.00037	0.00035	0.00045
Moisture absorption, % in 24 hr.	0.08	0.05	0.10

Extrusion and calendering

Tubes and profiles are produced on single-screw and double-screw machines, which are also used to apply insulation to electric wires and cables. Unplasticised film can be produced by extrusion.[5]

Calenders are used to convert stock into sheet and foil. Thicker rigid sheet is produced by laminating in multi-daylight presses.

The rheology of the melt, and the tendency of the compound to decompose at processing temperatures, caused the development of injection

'Darvic' general chemicals plant of I.C.I. plastics division at Runcorn.

moulding of PVC to be slow. New machines have satisfactorily overcome this problem and both rigid and plasticised PVC is now processed by this method.

Welding and machining

Rigid PVC can be sawn, drilled and machined on standard wood-working and metal-working machinery provided sufficient care is taken to use adequate cooling of the stock. Welding by hot gas and by solvents is quite easy, and large corrosion-resistant structures for the chemical industry have been produced by this method. A hot gas torch with an air temperature between 200 and 300°C. is recommended. Solvent-welded joints can be handled a few hours after welding, and after 48 hr. the strength of the joint is equal to that of the original material.

Rigid tube, rod and sheet stock can be shaped into its final form by a number of processes all of which depend on the thermoplastic nature of the material. It is softened by heat and then blown, sucked by vacuum or otherwise forced into cavity moulds or on to shaped formers. These methods are low cost operations as the equipment is simple and the capital outlay small.

Properties

For the construction of chemical plant rigid PVC is more important than plasticised PVC. Table 1 shows the differences in physical properties which can be expected with the different grades of PVC.[6] Suitably compounded PVC retains the extreme chemical inertness of the original resin. In the absence of ultra-violet light, compounds resist oxidation almost indefinitely. Compounded with the correct stabilisers and pigments their ageing characteristics are excellent. De Coste and Wallder[7] have reported many years' outdoor weathering for a compound protected by dibasic lead phosphite and rutile titanium dioxide.

A short-term ageing test on two types of PVC has been reported.[8] Table 2 shows the effects on physical properties of exposure at Florida. Unlike metals, no corrosion took place.

Plastics materials show creep characteristics which have to be considered in their use in the construction of chemical plant, or in their use for piping. For normal PVC the limiting load below which strain is proportional to stress is 2,500 p.s.i. For the high-impact grade the figure is about 2,000 p.s.i. Above this figure both the elastic and creep deformations increase faster than they do below this figure. This creep is relatively small at low loads, and for working calculations it is usual to use a safety factor of 5 to 1, and so arrive at a working tensile strength of $\frac{1}{5}$ of the ultimate tensile strength. For any piping the allowable working pressure can be calculated:

$$P = \frac{2t\ S}{d}$$

where

P = Working pressure
S = Working tensile strength
t = Wall thickness
d = Outside diameter of pipe

Flow properties of liquids over PVC surfaces compare very favourably with metals. A 2-in. PVC pipe carrying water at 60°F. at 100 gal./min. will show a pressure drop of only 8 p.s.i./100 ft. of pipe. Under similar conditions a clean steel pipe will show a pressure drop of 12 p.s.i./100 ft. of pipe and, when in use for a while and scale has formed, this pressure drop can be as large as 16 p.s.i./100 ft.

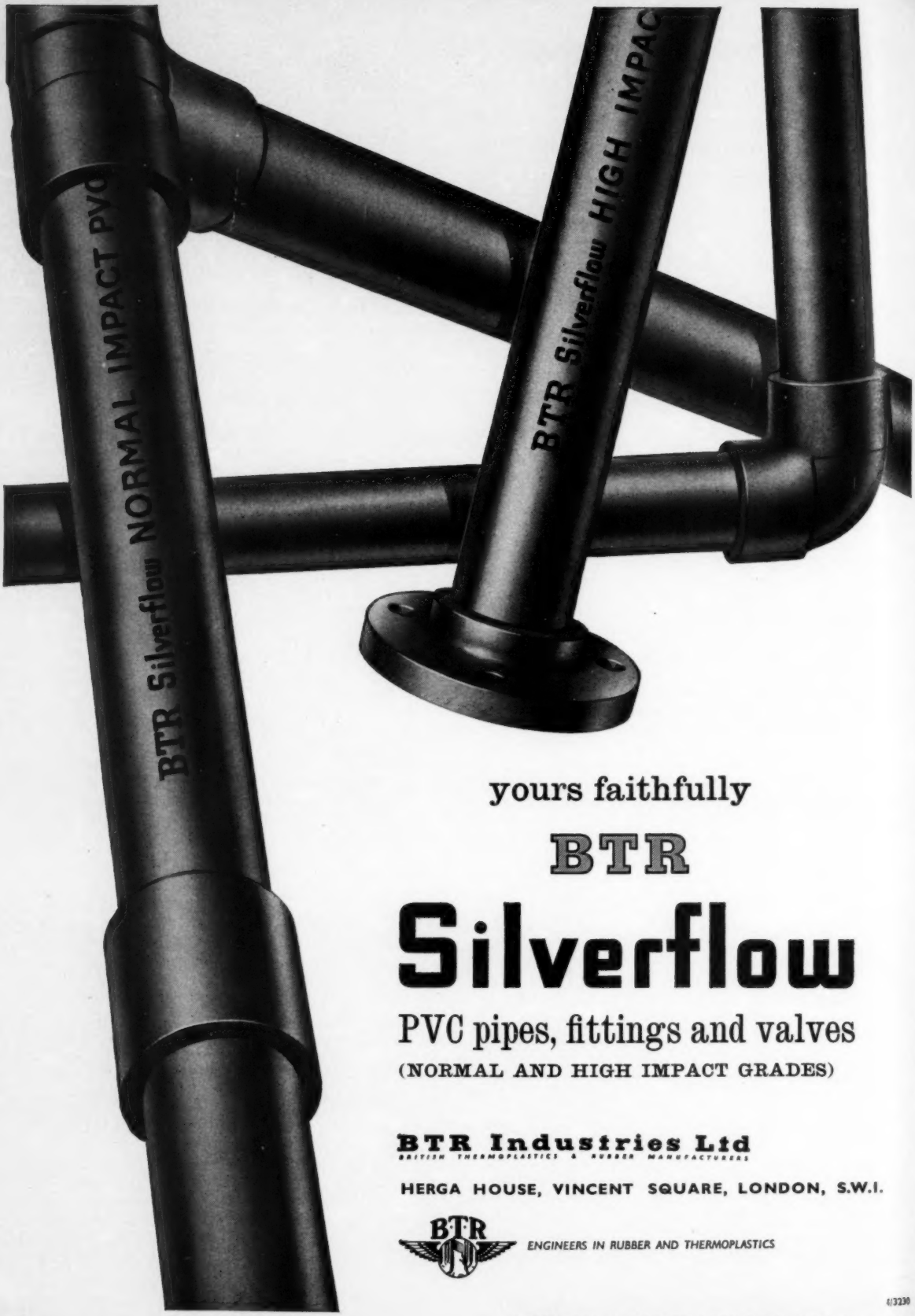
Resistance of PVC to chemicals is excellent. Tables 3, 4, 5 and 6 taken from trade literature[9] give information on this. The few materials to which it is not resistant include concentrated nitric acid, fuming sulphuric, acetic anhydride, ketones, aromatic amines and certain organic compounds containing chlorine and/or nitro groups. The high-impact grades have slightly poorer chemical resistance. PVC compounds in all grades are practically unaffected by water. A report summarised in Table 7 on the effects of heat and humidity showed that continued exposure to them caused negligible changes in weight or in dimensions.[10]

Table 2. Effect of exposure at Florida, U.S.A.

Exposure time	*Tensile strength, p.s.i.*		*Izod impact, ft.lb./in.*	
	Normal	*High-impact*	*Normal*	*High-impact*
Original	6,800	5,200	0.60	15.0
30 days	7,000	5,400	0.55	15.0
4 months	7,400	5,800	0.65	11.0
1 year	7,600	6,500	0.62	10.0
19 months	7,500	5,900	0.76	8.2
2 years	7,500	5,600	0.75	7.0
3 years	7,400	6,100	0.65	10.1

Use in chemical plant

The earliest use of rigid PVC in chemical plant was in Germany. A B.I.O.S. report in 1946[11] estimated a use of 3,500 tons rigid PVC in one year in the Bitterfeld area alone even in the earlier years of the second world war. This use was influenced by the shortage of metals; however, when metals were again plentiful use of rigid PVC for chemical plant continued. Study of German literature in the early fifties shows fume ducting up to 100 yd. long, fume stacks as high as 270 ft., complicated distribu-



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tion systems with many hundred welded joints, and many plating installations. The use of PVC for many miles of chemical pipework has been commented on earlier in this article.

At the same time, 1953, an article in *Chemical Age*[12] could report very little in the U.K. except that the plating industry in Britain was lining its tanks with rigid PVC as a protection against the corrosive action of plating solutions and acid fumes. It also reported that the production of rigid PVC piping had only just started in the British plastics industry.

The position at that time in the U.S.A. did not appear to be very different from that in the U.K. as regards the development of rigid PVC. In this case, however, the slowness of the development of rigid PVC was not solely due to the continued use of metals, but because other plastic materials, cellulose acetate butyrate and styrene butadiene co-polymer blends were indigenous to the U.S.A. and so were developed first.

Present-day applications

At the present time the use of rigid PVC in the chemical industry in the U.K. and in the U.S.A. has become firmly established. In the U.S.A. it has been shown to be capable of handling a wider range of corrosive chemicals more satisfactorily than any other material, either metal or plastic. There are successful pipe installations carrying sulphur dioxide gas, hydrochloric acid, sulphuric acid, nitric acid, chlorine, ammonium hydroxide and many types of salt solutions. In sheet form it has been used for ducting and tank linings to handle similar liquids. The second largest application is in industrial systems for water treatment, water handling systems and drain and discharge lines. In naval vessels the most important use of rigid PVC is in the spray systems to remove radioactive contamination. PVC pipe is being used in processing such products as wine, beer, vinegar, milk, mustard, fruit juices and bleaches. An important factor here is the absence of any taste or odour transmitted from the pipe to the contents. Surprisingly the development of PVC for domestic water services which has been important in Europe for many years has failed to develop in the U.S.A.

In the U.K. the use of PVC in process towers, storage tanks, reaction vessels and ducting has been developed faster than it has in the U.S.A. Large pieces of equipment such as ventilation

Table 3. Resistance of PVC to inorganic materials

Acids	*Maximum concentration by weight*	*Maximum operating temperature °C.*
Arsenic	Any	66
Carbonic	Sat. at atm. pressure	32
Chlorine water (hypochlorous acid)	,,	32
Fluoboric	Any	66
Hydrofluoric	60%	21
,,	4%	66
Hydrogen sulphide in water	Sat. at atm. pressure	32
Hydrochloric	Any	32
,,	22%	60
Nitric	10%	66
,,	20%	49
,,	35%	32
Phosphoric	75%	66
Sulphuric	50%	54
Sulphurous (sulphur dioxide in water)	Sat. at atm. pressure	32
Chromic acid	25%	54
Hydrogen peroxide	90%	32
Mixtures of acids		
Nitric Hydrofluoric Sodium dichromate	15% 4% 13%	60
Nitric acid Water	16% 71%	32

Table 4. Resistance of PVC to inorganic materials

Alkalis and salts	*Maximum concentration by weight*	*Maximum operating temperature, °C.*
Aluminium chloride	Up to saturation	66
Aluminium sulphate	,,	66
Alums	,,	66
Ammonium chloride	,,	66
Ammonium hydroxide	,,	32
Ammonium sulphate	,,	66
Barium sulphide	,,	66
'Black liquor' NaOH, Na_2S, Na_2CO_3	,,	32
Calcium bisulphite	,,	66
Calcium chloride	,,	66
Calcium hypochlorite	,,	32
Caustic soda (sodium hydroxide)	35%	32
Caustic soda (sodium hydroxide)	10%	66
Caustic potash (potassium hydroxide)	35%	32
Caustic potash (potassium hydroxide)	10%	66
Copper chloride (cupric)	Up to saturation	66
Copper cyanide (in solution with alkali cyanides)	,,	66
Copper sulphate (cupric)	,,	66
Disodium phosphate	,,	66
Ferric chloride	,,	66
Ferrous sulphate (copperas)	,,	66
Nickel acetate	,,	66

Table 5. Resistance of PVC to plating solutions

	Maximum concentration by weight	*Maximum operating temperature, °C.*
Brass, Cadmium, Copper, Gold, Indium, Lead, Nickel, Rhodium, Silver, Tin, Zinc	—	66
Chrome plating	—	54
Potassium cuprocyanide	Up to saturation	66
Potassium dichromate	,,	66
Sodium or potassium antimonate	,,	66
Sodium or potassium bisulphite	,,	32
Sodium or potassium acid sulphate	,,	66
Sodium or potassium chloride	,,	66
Sodium or potassium cyanide	,,	66
Sodium or potassium hypochlorite	,,	32
Sodium or potassium sulphide	,,	66
Sodium or potassium thiosulphate	,,	66
Tin chloride—either stannous or stannic	Any aqueous solution	66
Trisodium phosphate	Up to saturation	66
Zinc sulphate	,,	66

unbreakable bonds

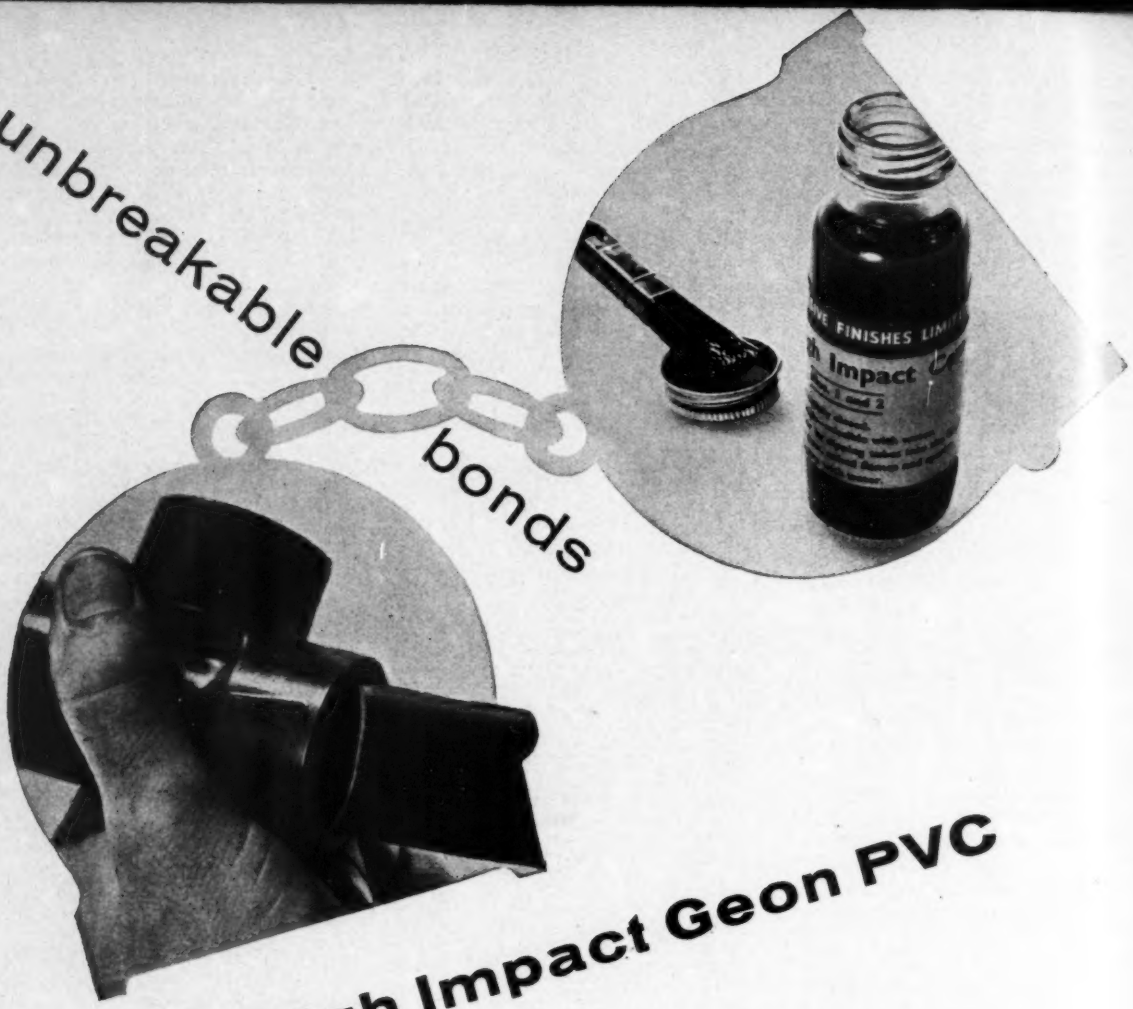

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Table 7. Changes in rigid black PVC tubing under durability tests

Conditions of test	*Period of test in days*	*Total change in dimensions, parts/thousand*		*Total change in weight, %*
		External diam.	*Internal diam.*	
Extended dry heat at 60°C.	1	None	−3.5	−0.11
	10	+1.3	−6.0	−0.22
	30	+1.3	−3.5	−0.34
	100	+2.0	−6.0	−0.40
Continuous water absorption	1	−0.6	−19	+0.02
	10	None	−19	+0.14
	30	+1.3	−14	+0.23
	100	+3.0	−13	+0.55
	200	+5.0	−10	+0.86
	300	+5.0	−11	+0.88
	400	+5.0	−10	+0.90
Fluctuating warmth and humidity	1	+0.6	+7	+0.05
	10	+1.3	+14	+0.07
	30	+3.3	+15	+0.09
	100	+4.0	+15	+0.05
	200	+6.0	+16	+0.03
	300	+4.6	+16	+0.03
	400	+4.6	+16	−0.03

Table 6. Resistance of PVC to organic materials

Alkalis and salts	*Maximum concentration by weight*	*Maximum operating temperature °C.*
Amyl alcohol ..	Any	32
Butyl alcohol ..	,,	32
Castor oil ..	,,	32
Citric acid ..	Up to sat.	66
Cottonseed oil ..	Any	32
Coconut oil ..	,,	32
Ethyl alcohol ..	,,	32
Ethylene glycol ..	,,	32
Food products ..	,,	32
Gallic acid ..	Up to sat.	66
Glucose	Any	66
Glue	,,	66
Glycerine ..	,,	32
Hydroquinone ..	,,	32
Lactic acid ..	,,	32
Maleic acid ..	,,	32
Methyl alcohol ..	,,	32
Mineral oils ..	,,	32
Oleic acid ..	,,	32
Oxalic acid ..	,,	32
Propyl alcohol ..	,,	32
Soaps	,,	66
Tannic acid ..	Up to sat.	32
Tartanic acid ..	,,	32
Triethanolamine ..	Any	66

and exhaust ducting, rotary drum filters, gas washing towers, fan impellers and castings, and storage and reaction tanks have been constructed in the past few years. However, this application still lags behind Germany. Some of these pieces of equipment are shown in the illustrations. Recent developments enable larger structures to be built. One of these is a combination of rigid PVC with polyester glass-fibre laminate.[13] A process tower 24 ft. high and 4 ft. in internal diam. constructed from this material is strong enough to take the weight of 4 tons of tower packings. Fume ducting made from this material is reported to have been operating for several months at 120°C. Another interesting combination is the coating of steel strip with PVC. The resulting materials have the strength of steel and the chemical inertness of PVC.

Piping

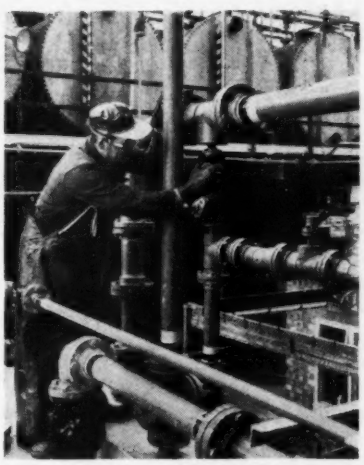
This use of rigid PVC is developing faster than is its use in the fabrication of equipment. The main uses are for water pipe, gas pipe, conveying chemicals and oil, and for effluents. In many soils buried iron pipes corrode rapidly. Sewer water undertakings, an atomic energy research station and a gas board have all installed PVC piping, also 4 to 12-in. effluent pipes are in use to convey acid waste at many factories. Five miles of 12-in. pipe conveying concentrated potash solution from the Dead Sea to evaporating pans was made in the U.K.

A bar to this development has always been the lack of fittings (bends, collars, flanges and T joints), but now that these are being produced in this country the number of installations should increase rapidly. In a comment on the more extensive use of PVC for water service pipes on Europe, in an article in *Water Research News*,[14] it is remarked that but for the accidents of history PVC would already be extensively used in Britain!

Conclusions

The outstanding property of rigid PVC is its chemical inertness. It has a high degree of resistance to corrosive chemicals, combined with excellent weathering properties, and is unaffected by moisture. It is lighter than metals, will not burn and has good electrical insulation properties. It can be either glass-clear, translucent or opaque, is cheap and is easily fabricated.

Its disadvantages are that it is a thermoplastic material and consequently subject to limitations of temperature and working loads. The more recent development of combining rigid PVC with a polyester glass-fibre laminate will minimise this. These factors coupled with greater availability of fittings and with wider experience in the welding and machining of rigid PVC will allow this material to be used more and more in the following applications: chemical industry, irrigation and domestic water supply, gas main and service lines, general services, oil fields and lighting and glazing.



A section of the 'Silverflow' PVC system at Murgatroyds Salt & Chemical Co. Ltd. showing storage tanks in the background to which sodium hypochlorite liquor is conveyed. Similar piping is used in this factory for the handling of hydrochloric acid.

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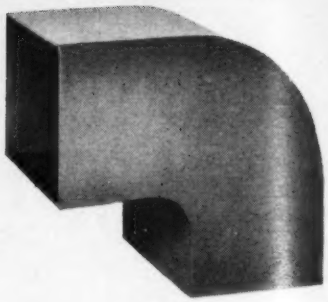

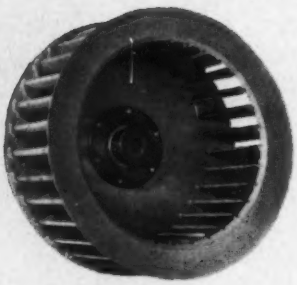

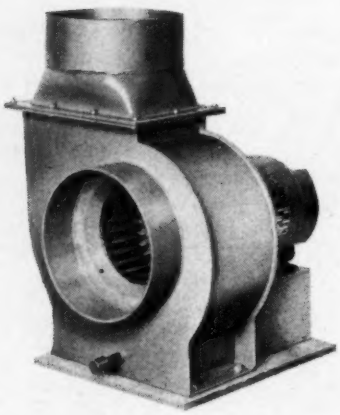

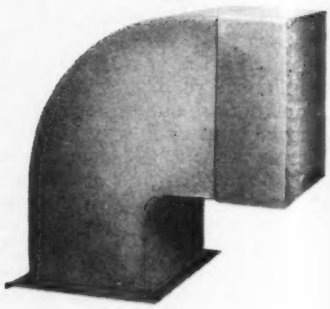

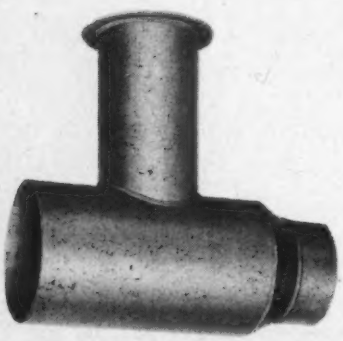

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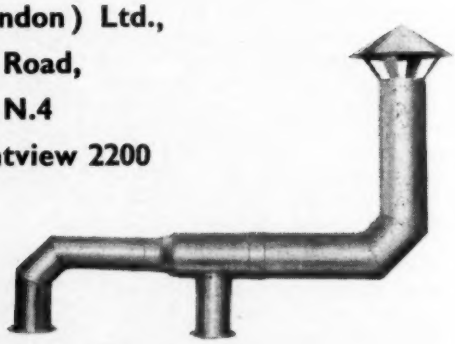

Formulation of Gamma-radiation-resistant PVC

By H. Wells,* A.R.I.C., and I. Williamson,† B.Sc.

IN the construction of nuclear power stations and laboratories, for instance in remotely operated ' hot ' cells, cooling ponds and other places, there is a need for elastomeric materials from which to fabricate gaskets, flexible sheathing, coverings, etc. These materials are required to operate at somewhere near ordinary temperatures (0 to 30°C.) and under bombardment from the radiations of nearby radioactive materials, the most important of which is the gamma radiation, because of its abundance and its penetrating power. Furthermore, they are often subject to frequent decontamination procedures and should therefore be readily decontaminated and resistant to deterioration by the action of aqueous and organic liquids. Many investigations of the behaviour of elastomeric materials inside the pile shielding have been reported, but the conditions inside the biological shield are very different from those of interest here and it was felt by A.E.R.E. that it would be worthwhile to investigate the behaviour of likely materials under conditions more nearly resembling those described above.

A beginning has been made in the case of plasticised PVC and the first series of experiments has shown that there are marked differences in the behaviour of plasticised PVC, depending upon which plasticiser is used.

Formulation

Five plasticisers were selected for test, three primary ester-type plasticisers representing the three main ester groups (phosphates, phthalates and sebacates) and two high-molecular-weight polyester types because of their resistance to extraction and evaporation. The five plasticisers were:

- Tritolyl phosphate (TTP)
- Di 2 ethyl hexyl phthalate (DOP)
- Di 2 ethyl hexyl sebacate (DOS)
- Polypropylene sebacate (*Reoplex* 100)
- Polypropylene sebacate modified (*Reoplex* 110)

No other variables were investigated in this part of the work, and the formulation used was:

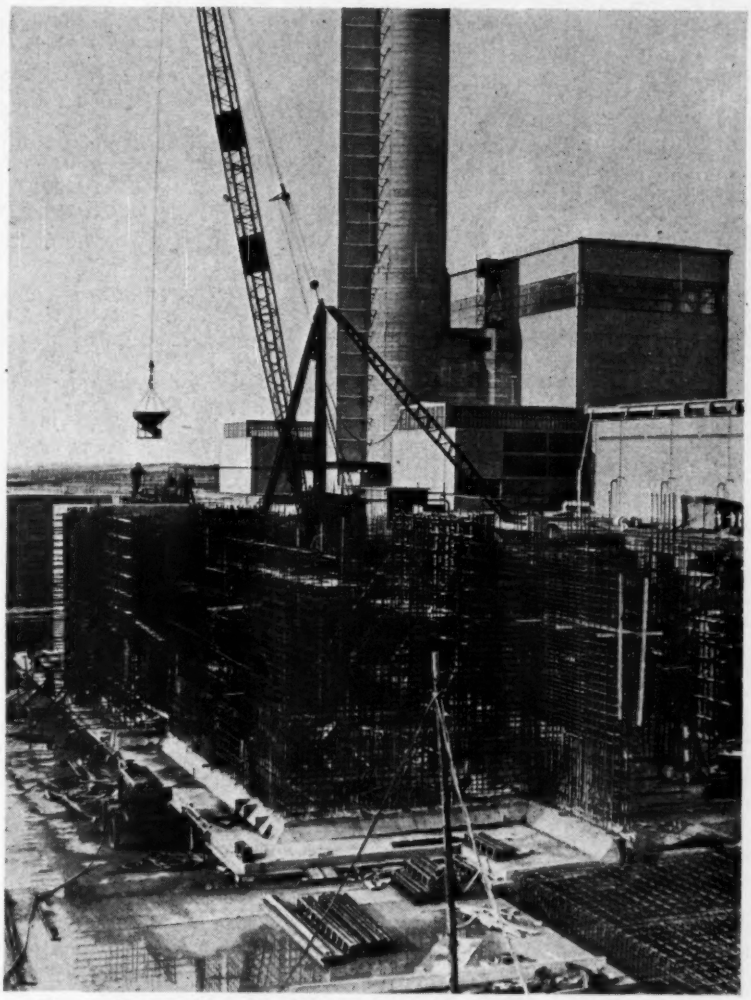

Fig. 1. Construction of cooling pond in which PVC water-stop is used.

	Parts by weight
PVC polymer (dispersion type)	60
Plasticiser	40
White lead paste (7 : 1 in DOP)	5

Mechanical properties

The compositions were milled and pressed, and 6 × 3 in. pressed sheets exposed to gamma radiation from a cobalt-60 source. Exposures of 5.0×10^7 and 1.0×10^8 roentgens were given. After exposure, dumb-bell specimens were cut from the sheets and tested for tensile strength and elongation at break at 25°C. Table 1 shows the results obtained (each figure is an average of five samples).

From the tensile strength and elongation it is possible to calculate two quantities which are rather more informative. They are the tensile product and the tensile modulus. The

*A.E.R.E. Harwell. †The Geigy Co. Ltd.

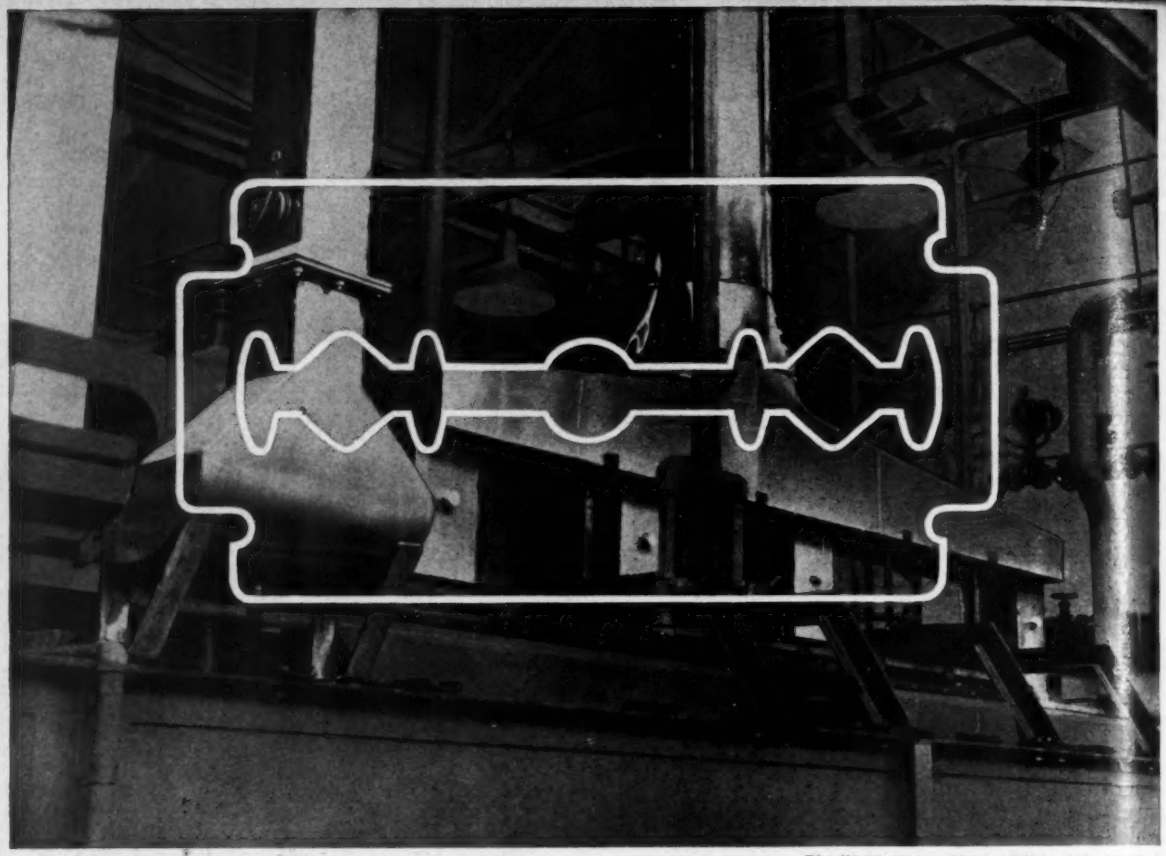

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Table I

	Blank (no exposure)		5×10^7 r		1×10^8 r	
	Tensile strength, kg./sq.mm.	Elongation	Tensile strength, kg./sq.mm.	Elongation	Tensile strength, kg./sq.mm.	Elongation
TTP	1.50	3.18	1.12	2.08	1.04	1.68
DOP	1.34	3.64	0.47	1.20	0.33	1.16
DOS	0.92	3.18	0.13	0.44	0.04	0.48
Reoplex 100 ..	1.44	3.42	1.01	1.58	1.04	0.60
Reoplex 110 ..	1.38	2.84	1.14	1.94	1.21	1.00

Table 2. Tensile product and tensile modulus

	Blank (no exposure)		5×10^7 r		1×10^8 r	
	Tensile product	Tensile modulus	Tensile product	Tensile modulus	Tensile product	Tensile modulus
TTP	4.79	0.473	2.32	0.540	1.74	0.624
DOP	4.88	0.368	0.56	0.391	0.39	0.289
DOS	2.93	0.289	0.06	0.308	0.02	0.098
Reoplex 100 ..	4.93	0.421	1.60	0.641	0.63	1.750
Reoplex 110 ..	3.94	0.488	2.22	0.587	1.21	1.210

tensile product is the product of the tensile strength and the elongation; it is roughly proportional to the work done in breaking the specimen, and it is largely dependent upon the polymer network. As both tensile strength and elongation fall with polymer degradation, the tensile product is very sensitive to it, and is relatively insensitive to variations in plasticiser content. The tensile modulus is obtained by dividing the tensile strength by the elongation, and is roughly proportional to the modulus of elasticity of the material. It is very sensitive to variations in the plasticiser content. These quantities are shown in Table 2.

The results show clearly that there is a great difference between the behaviour of compositions containing different plasticisers. In all cases there is a fall in the tensile product, but the behaviour of the modulus divides the plasticisers into two groups, those in which there is an increase in the modulus (TTP and the *Reoplexes*) and those in which there is a decrease in the modulus (DOP and DOS).

On the basis of these results, TTP is to be preferred as a plasticiser, since it shows the smallest drop in tensile product and the smallest change in modulus. It also has the advantage of being one of the best of the non-polymeric plasticisers in resistance to extraction.

Observations of the colour changes of the specimens were made. TTP, *Reoplex* 100 and *Reoplex* 110 darken considerably to dark brown or black while DOP and DOS showed much less change and became only slightly darker than a creamy shade.

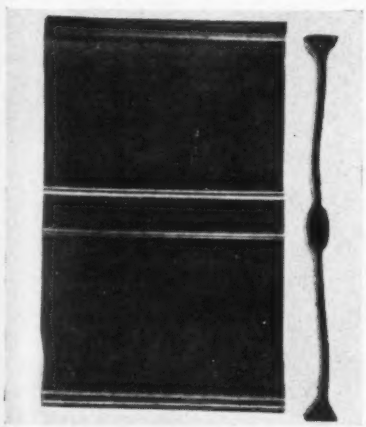

Fig. 2. PVC water-stop made by Expandite Ltd.

Contamination

All samples were contaminated to a larger extent where acidic fission products were used. Visual damage was noticeably large in all cases but especially in the cases of the polymeric plasticisers. The most interesting results were obtained using aqueous fission products. The level of contamination retained on the polymeric plasticised samples was reduced considerably by increasing the radiation dose. This could possibly be explained by a decrease in diffusion rate through the polymer lattice brought about by cross-linkage.

Conclusion

The results clearly indicate that PVC compounds plasticised with tritolyl phosphate show less physical deterioration under gamma irradiation than those made with the other plasticisers tested. The two *Reoplexes* were second best. Other properties do not necessarily correlate with mechanical breakdown, *e.g.* di octyl sebacate showed the least colour change and was the most flexible of the irradiated samples.

Institution of Chemical Engineers annual dinner

A healthy state of growth was reported by the president of the Institution of Chemical Engineers, Mr. W. K. Hutchison, C.B.E., at the annual dinner held in London on April 12. He said that there were now well over 5,000 members of the Institution and this number was increasing at the rate of 600 a year. There were now over 1,500 student members, as many as the number of associate members. Mr. Hutchison said that nowhere in Western Europe was there an established system of chemical engineering education equal to the British. The rapid growth of the Institution threw a heavy burden on the general secretary, Dr. Brennan, said Mr. Hutchison, and he paid tribute to the work of the secretary and his small staff.

Mr. Hutchison was welcoming the guests who included Mr. Richard Wood, Minister of Power, Sir Henry Jones, chairman of the Gas Council, Sir William Garrett, chairman of the A.B.C.M., and Sir Cyril Hinshelwood, president of the Royal Society.

In his speech, Mr. Wood urged chemical engineers to do their utmost to reduce costs in industry. The Government intended to allow consumers to continue to choose the kind of fuel they wanted and this freedom entailed keeping costs to a minimum.

In his response to the toast to the guests proposed by the president, Sir Cyril Hinshelwood said he was particularly gratified to attend the dinner because Mr. Hutchison was a former pupil of his. 'When you find tycoons among your former pupils, it makes life less terrifying', said Sir Cyril. Referring to the development of the chemical engineer over the past 40 years, Sir Cyril characterised him as a man who overcame not only the 'cussedness of matter', but also the 'cussedness of men'. He was an interpreter between chemists and engineers. Chemists knew what was to be done and engineers how to do it. The chemical engineer bridged this gap.

The dinner was followed by a dance.

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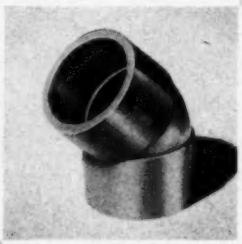

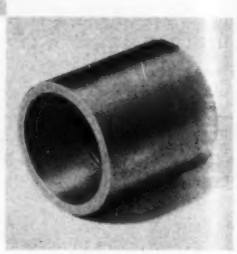

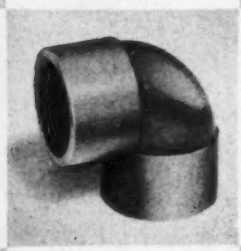

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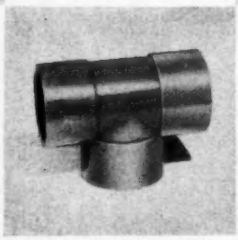

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Thermoplastic Pipe Systems for Chemical Plant

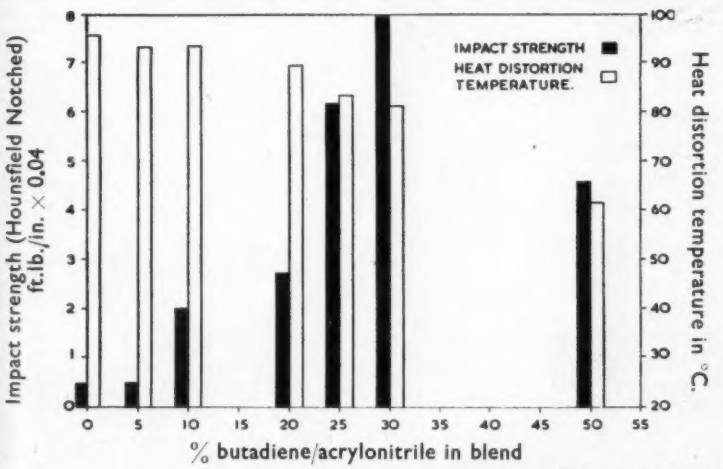
One of the major applications of PVC in chemical plant is in pipelines and ducting, where it is displacing conventional metals. The fact that most pipelines operate under pressure has necessitated modification of PVC to increase its impact strength. High-impact PVC together with ABS polymers are the only thermoplastics used for pipe systems in the U.K. This article discusses the properties of both plastics and their suitability for pipe systems.

WHEN considering the special function of particular plastics for pipe systems in chemical plant, it would seem desirable to establish some general requirements that may be listed as follows:

(*a*) Resistance to the particular type of chemical attack which makes traditional materials unsuitable.
(*b*) Sufficient strength to give a safety factor necessary when handling dangerous fluids and gases.
(*c*) Availability of fittings to complete the installations.
(*d*) Reasonable temperature range.
(*e*) Acceptable and competitive price.

There are several thermoplastic materials which comply to some extent with requirement (*a*) and one or two which comply with requirement (*b*). With regard to (*c*) there was a lamentable lack on the British market for many years of a reasonable range of fittings. This resulted in a crude attempt to complete installations by hand-made fabricated joints of one type or another, few of which were really suitable for pressure applications. As regards (*d*), with the exception of nylon and *Teflon*, most thermoplastics have a limiting temperature for use under pressure of between 50 and 60°C. which gives very little safety margin under normal operating conditions. In the case of nylon, on the other hand, the chemical resistances cover only a limited field, whilst the high price and difficult processability of *Teflon* makes it uneconomical except for a few specialised applications. With regard to (*e*) there have been several ill-judged attempts to introduce thermoplastic pipe systems into markets where conventional materials such as mild steel are at present perfectly satisfactory.

As a result only two thermoplastics, ABS polymers and high-impact PVC, seem to occupy a special place in the chemical pipe field. For this reason it is proposed to consider the properties and uses of these plastics in detail.


IMPACT STRENGTH
HEAT DISTORTION TEMPERATURE.
Impact strength (Hounsfield Notched) ft.lb./in. × 0.04
Heat distortion temperature in °C.
% butadiene/acrylonitrile in blend
0 5 10 15 20 25 30 35 40 45 50 55
0 1 2 3 4 5 6 7 8
20 30 40 50 60 70 80 90 100

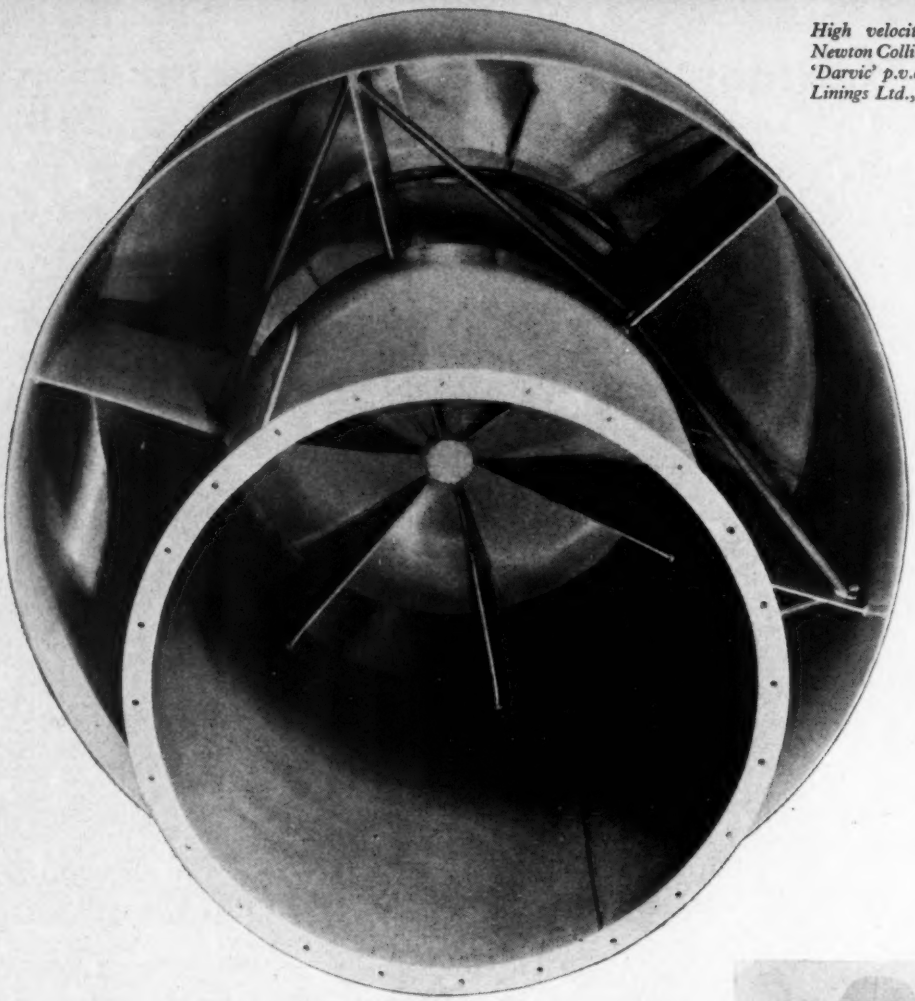
Reproduced from 'Rubber and Plastics Age'

Fig. 1. Effects of successive additions of butadiene/acrylonitrile to styrene/acrylonitrile resin on heat-distortion temperature and impact strength.

One-fifth the weight of steel, non-corrodible, shatterproof 'Hipact' piping.

ABS polymers

It can be said that the development of ABS polymers is the result of demands to improve upon the properties of polystyrene in specific directions, and that the resultant products are therefore successful or otherwise dependent upon the success of the modifications. The first of these materials which secured any large-scale acceptance was *Kralastic*, manufactured by the Naugatuck chemical division of the U.S. Rubber Co. This is a styrene/acrylonitrile co-polymer blended with butadiene/acrylonitrile co-polymer, *i.e.* nitrile rubber. The simple styrene/acrylonitrile co-polymer has a better heat distortion temperature with only slightly improved impact strength when compared with polystyrene. By the addition of butadiene/acrylonitrile the impact strength increases up to a maximum value at 25% butadiene/acrylonitrile content, while the heat distortion temperature falls slightly, as is to be expected. This is illustrated in Fig. 1.



High velocity cowl design by Newton Collins Ltd. and made from 'Darvic' p.v.c. sheet by Tanks and Linings Ltd., Droitwich.

Tough, corrosion-resistant 'Darvic'

clears the air for Serck Tubes Ltd.

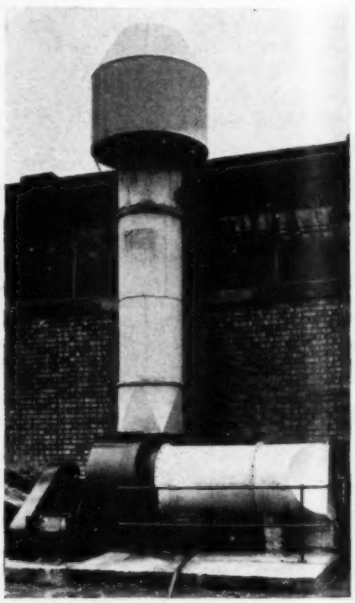
This ventilation duct and its cowling were made from Industrial Grade 'Darvic' p.v.c. sheet by Tanks and Linings Ltd. for Serck Tubes Ltd.

'Darvic' is light, rigid even in thin sheets, corrosion-resistant, easily cemented and no trouble to clean. It can be made in a wide range of colours.

Ducts and cowls made from 'Darvic' not only stand up to most industrial and chemical fumes, they are also easily transported, assembled and maintained.

'DARVIC'

'Darvic' is the registered trade mark for the rigid p.v.c. sheet made by I.C.I.



Ducting 3 feet in diameter, with a 5 feet 6 inches diameter, 8 feet high cowl, fabricated from Industrial Grade 'Darvic' by Tanks and Linings Ltd., Droitwich and installed at SERCK TUBES LTD. (Main Contractors, Newton Collins Ltd.)

ICI IMPERIAL CHEMICAL INDUSTRIES LIMITED · LONDON S.W.1

PD.79

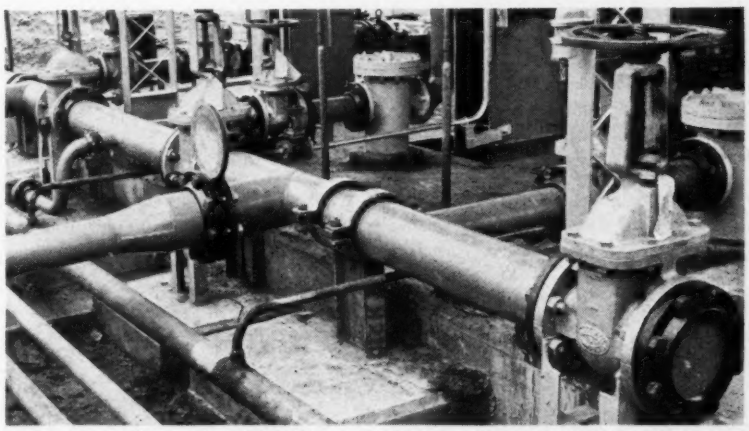
Table 1. Comparison of ABS polymers and high-impact PVC

Property	*ABS polymers*	*High-impact PVC*
Specific gravity	1.0 to 1.1	1.35 to 1.45
Heat-distortion temperature	85 to 90°C.	65 to 70°C.
Impact strength	High	High
Thermal conductivity (B.Th.U./hr./sq.ft.°F./in.)	1.0	4.5×10^{-4}
Coefficient of linear expansion (°F.)	5.6×10^{-5}	10×10^{-5}
Specific heat (cal./°C./g.)..	0.35	0.25
Extrudability	Extrusion very easy over wide temperatures	Extrusion satisfactory with careful temperature control
Heat stability	Will stand at least 30°C. over the normal optimum extrusion temperature. Decomposition products are non-corrosive.	Not practicable to use temperatures much above 190°C. due to decomposition with evolution of HCl. Plated or stainless equipment essential.
Chemical and oil resistance	Good	Good
Flame resistance	Slow burning	Self-extinguishing
Cost	ABS polymers are about 20% greater in cost on volume basis compared with high-impact PVC	
Weathering	Certain grades of pigmented black piping have excellent resistance; some loss of impact strength on exposure	

Other manufacturers in the U.K. are now manufacturing ABS polymers, although their material differs in a number of respects because of patent coverage enjoyed by the U.S. Rubber Co. There are, for instance, the *Cycolacs*, which are single terpolymers of styrene/acrylonitrile/butadiene. The behaviour of this group in general is the same as above and they have therefore all been given the class name of ABS polymers.

High-impact PVC

Like polystyrene, polyvinyl chloride suffers from a fairly low impact strength—its Izod impact strength at 23°C. is only 1 ft.lb./in. notch—and this has been a considerable drawback to its use in piping installations. By suitable additions of butadiene/acrylonitrile the impact strength is increased by more than 15 times. High-impact PVC, only made by British Geon in the U.K., can be considered a physical blend of polyvinyl chloride with butadiene/acrylonitrile, but not a co- or ter-polymer like the *Cycolacs*. Table 1 gives the properties of *Kralastic* B (ABS suitable for pipe extrusion) and *Geon R.A.* 170 (high-impact PVC suitable for pipe extrusion). The advantages and disadvantages of using either material can be seen from this table which is reproduced from *Rubber and Plastics Age*.



Part of a system made with 'Hipact' tubing, used to handle acid effluent and installed at the Isle of Grain refinery of the British Petroleum Co.

One significant advantage of ABS lies in its higher heat distortion temperature, 85°C., compared with that of high-impact PVC, 65°C. Coupled with this is the probable decomposition hazard at excessive extrusion temperatures of high-impact PVC; there is considerably less decomposition hazard for ABS polymers. Mention must here be made of a new high-temperature-resistant ABS grade, *Kralastic HTHT*, which, although more difficult to process, has a heat-distortion temperature of 107°C. Weathering resistance of both materials is similar; both high-impact and ABS satisfactorily withstood three years' sunlight exposure with only a small decrease in impact strength.

Flame resistance and cost

An advantage of high-impact PVC is its self-extinguishing property when subjected to a flame. This is, of course, due to the chlorine content. ABS polymers, on the other hand, burn slowly when similarly subjected. The factor which in the end is all-decisive is cost. In this respect high-impact PVC is 20% cheaper even when compared on a volume basis. Naturally, potential users would require much evidence of the superiority of the more expensive ABS before deciding on its use. Experience is showing, however, that many sections of the chemical industry in the U.K. prefer the extra safety factor inherent in the better impact strength and higher heat-distortion value of ABS polymers.

In general it can be stated that the resistance to chemical attack of ABS polymers is similar to PVC except in the case of very concentrated mineral acids.[1] Both materials are therefore suitable for a very wide field of applications including oils and water, both potable and demineralised.

Pipe systems of ABS polymers are limited in the U.K. to sizes up to and including 6 in. nominal diam. At the moment, development beyond this range for pressure pipes is likely to be somewhat expensive. Nevertheless, it is understood that plans are in an advanced state for taking the range up to 8, 10 and even 12 in. The only limiting factor for these large sizes

has been the absence of a suitable range of fittings, but these too are soon likely to be introduced.

Both in the U.K. and on the continent of Europe no official specifications for wall thickness/pressure rating ratios have been laid down for thermoplastic pipes. This is in some measure due to the comparatively new application of this material to water services. In the U.S. specifications have been drawn up to fit with existing metal pipe diameters. Certain recommended specifications are now being made to the British Standards Institute and it is fully expected that these recommendations will be approved and adopted as British Standards for thermoplastic pipes.

Pipe laying and jointing

Due to the low specific gravity of high-impact PVC and ABS polymers the piping is very light to handle—in fact its weight is only about one-fifth that of steel pipe of similar size. One man can easily handle a 19-lb., 20-ft. section of 3-in. pipe, the metal equivalent of which would weigh over 100 lb. This low weight factor, coupled with the simple but highly efficient jointing techniques outlined below, means that two men can lay one mile of 3-in. pipe (making all joints secure) in only 8 hr.; a similar length of metal pipe would take 24 to 30 hr. to lay, while a mile of 3-in. cement-lined pipe would take some 80 hr.

Amongst the advantages of piping is the facility with which it can be jointed. A complete range of fittings, both screwed and plain, can be made, *e.g.* tee-pieces, bends, elbows, reducers, unions and valves, all suitable for use with water piping. Special connections are also available for coupling up thermoplastic piping to metal pipe installations. Thermoplastic pipe can be sawn, filed, chamfered and threaded as easily as wood and is therefore very simple to work.

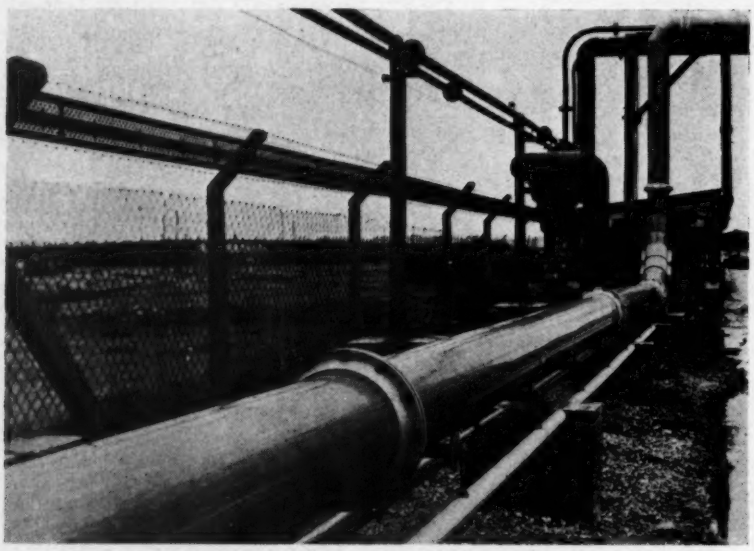
Four main forms of jointing are possible with thermoplastic pipes, which are briefly outlined below. Two operators, using any of these methods, can complete a perfectly leakproof joint in a short time.

(i) *Solvent welding*. Plain socketed fittings and flanges can be jointed with a special solvent cement.

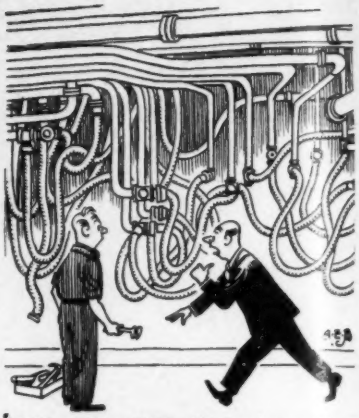
(ii) *Threading*. Threads may be cut on the ends of pipe sections and the sections joined by means of any of the threaded fittings described above.

(iii) *Heat welding*. Heat-welded joints can be made by means of a hot-air gun and filler rod. This method should generally be restricted to skilled operators.

(iv) *Shrink fitting*. Pipe ends can be belled at temperatures of the order of 120°C. (248°F.) and the male end slipped into this section; further heat applied causes the belled end to shrink fit tightly on to the other section of pipe to give a watertight joint ready for immediate use.



Part of a 400-ft. length of 12-in. 'Hipact' pipe which serves to remove effluent from the Barry factory of British Geon Ltd. The piping has remained unaffected by the sulphuric and hydrochloric acids contained in the effluent. 'Hipact' is high-impact PVC made by Extrudex Ltd.



"BEFORE YOU GO ANY FURTHER, SMITH, WE'VE JUST HAD A WARNING THERE'S A SNAKE ESCAPED FROM THE ZOO"

Solvent welding

Simple repairs to small fractures can easily be made without the necessity for excavating and replacing a whole section of pipe. A short piece of piping of sufficient length to cover the damaged portion may be cut, split longitudinally, heated and softened so that it may be slipped over the damaged section and welded in position with solvent cement.

It is not easy to obtain details of the actual conditions under which installations have been working for long periods of time, particularly when an installation is satisfactory.

Information is given below of two *Geon* PVC pipe installations, the first of which has been subjected to corrosive conditions of extreme severity.

(1) Formerly, a chlorinated rubber-lined 6-in. metal pipe, several hundred feet in length, was used to discharge a hot and highly corrosive effluent consisting of chlorinated brine at a temperature of 60°C. (140°F.). After barely a year it was so corroded that it had to be scrapped. Continued use of rubber-lined piping would have involved expensive replacement at least once a year. An alternative material was sought and in 1955 a 6-in. high-impact PVC pipeline was substituted and this has now been functioning satisfactorily for almost three years without any signs of corrosion or deterioration.

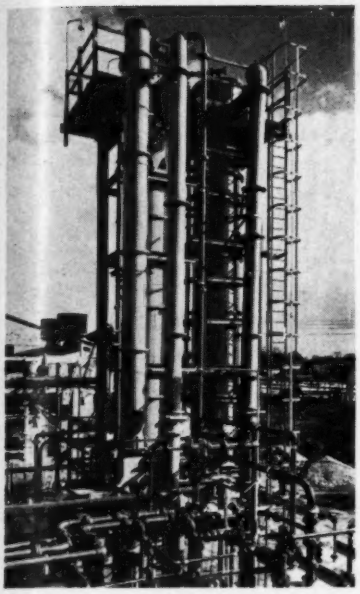
(2) In San Antonio Parks, Texas, 25,000 ft. of 1½-in. pipe put down early in 1956 has given completely satisfactory service at 70 to 75 p.s.i. Less head loss has been experienced and resistance to local soil corrosion conditions has been achieved.

The chemical engineer is by nature a cautious individual who quite rightly

(*Concluded on page* 201)

Fabricators and Their Products

A review of new developments in PVC for chemical plant



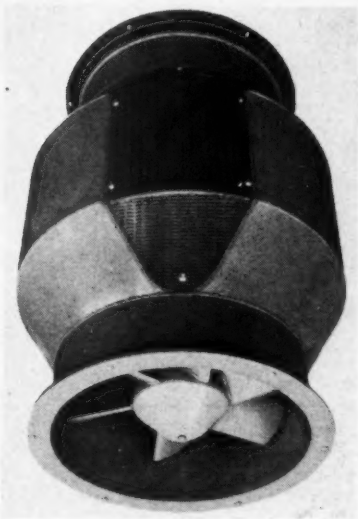
Wash towers for the chlorine adsorption plant on which are used 'Silverflow' PVC pipes and fittings for handling sodium hypochlorite liquor.

ALTHOUGH there are numerous companies in Britain which fabricate PVC, only a small proportion specialise in units for chemical plant. The reasons for this are that, firstly, the potential market for PVC in chemical plant is at the moment much smaller than for instance in domestic appliances, clothing or electrical goods. Secondly, a higher degree of skill is required by the fabricator of, for instance, a gas scrubber or pickling tank than would be required for injection moulding of toy soldiers or calendering sheet for rainwear.

This combination of a small potential market coupled with skilled labour is certainly not as attractive to the industrialist as a large market for which semi- or unskilled labour can work. Nevertheless, those fabricators specialising in PVC for chemical plant are steadily increasing their market as a result of the many attractive features of this material. However, due to the excessive caution exercised by plant engineers, this process of conversion is often retarded until final proof of superior ageing and corrosion resistance can be clearly demonstrated. To illustrate the versatility of the fabricator, some interesting new developments of plant made from PVC will be mentioned in this article.

Wash towers

A typical installation using BTR *Silverflow* pipes and fittings is illustrated in the photograph of the plant at Murgatroyds Salt & Chemical Co. Ltd., Sandbach, Cheshire. This system is used in the processing and subsequent conveyance to storage tanks of hydrochloric acid and sodium hypochlorite liquor manufactured by this company.



Bifurcated fan.

Bifurcated fans

A new range of PVC bifurcated fans for removal of fumes has been developed by Turner & Brown together with Matthews & Yates Ltd. Using true aerofoil section blades in rigid PVC and improved fabrication technique in the formation of the cases, manufacturers claim an excellent performance. These fans are available up to 30 in. diam.

Dip-coating

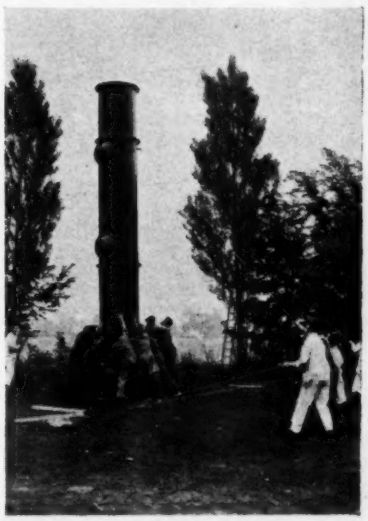
A new PVC powder for dip coating, *Telcovin A*, has been developed by the plastics division of the Telegraph Construction & Maintenance Co. Ltd. This enables powder dip-coating to be employed as an effective alternative to the current method of coating with plastisols. The coating provides a tough yet flexible finish with good resistance to inorganic chemicals and mineral oils.

PVC-polyester laminate

The use of unplasticised PVC as an engineering material is considerably enhanced by chemically bonding it to a layer of polyester resin reinforced with glass-fibre mat. This particular method of bonding has been developed and patented by Tough Plastics Ltd., who claim that they are the only fabricators who effect lamination by means of a chemical bond. The dual laminate of PVC and reinforced polyester resin is called *Tufplas*, and combines the chemical resistance of unplasticised PVC with the physical strength of the polyester laminate. A variety of chemical plant has already been fabricated from this laminate, and ducting systems are in use at a temperature up to 120°C. An advantage of the fabrication method is that expensive moulds and formers are unnecessary.

Ducking-rollers

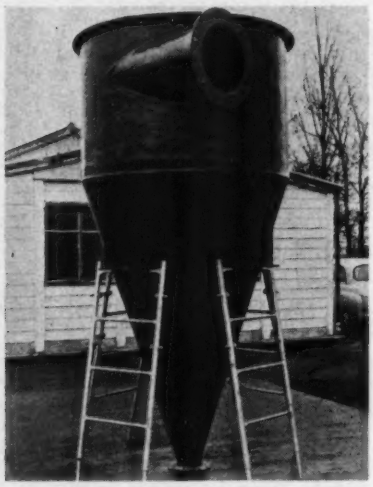
The pickling of continuous stainless-steel strip involves the immersion of the metal in a bath of nitric/hydrofluoric acid at a temperature of about 65°C. Ducking-rollers used to depress



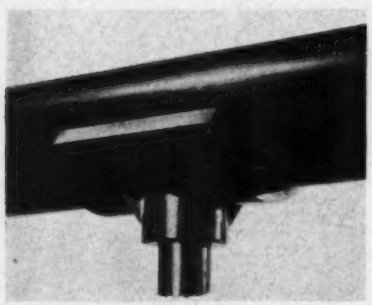
Plastic process tower, made by Tough Plastics Ltd., being erected for test

the strip into the acid bath must, of course, be fully resistant to the chemical conditions and must also withstand the considerable mechanical stresses involved. A further and very necessary feature of such rollers must be that they shall not mark the high-quality strip being produced so that no material of construction will be tolerated which will pick up and retain metal from the strip and subsequently scratch it.

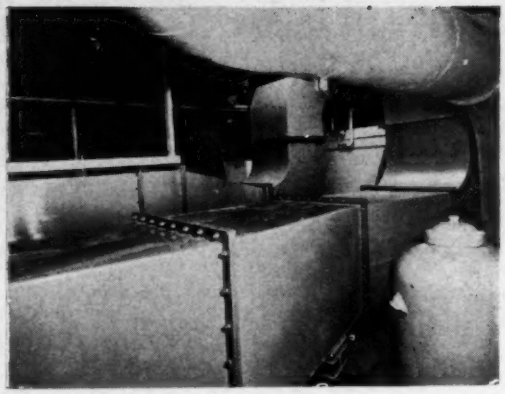
The rollers shown in the photograph are constructed almost entirely from PVC and the latest development is to provide a final outer covering of plasticised PVC. With the exception of a central steel shaft, which is fully protected, there are no metallic parts whatsoever. The stub shafts on the ends of the rollers are designed to run in carbon and PTFE bearings, but a variety of end conditions can be provided.



A cyclone unit fabricated in 'Tufplas' for use at 80°C. 'Tufplas' is a dual laminate of PVC and reinforced polyester resin.



Thermoplastic saddle made from ABS enabling branches to be cement-welded to existing pipelines without breaking. Made by Durapipe & Fittings Ltd.



Fume exhaust ducting rectangular bends for connections of exhaust duct to plenum section made from 'Cobex' rigid PVC. Fabricated and installed at the National Chemical Laboratory at Teddington by Redweld Ltd.

Thermoplastic saddles

A wide range of thermoplastic saddles which enable branches to be cement-welded to existing pipelines without the necessity of breaking to insert tee-pieces, have been developed by Durapipe & Fittings Ltd. The range consists of saddles for 3-, 4- and 6-in. pipe with off-takes in the case of the 6-in. pipe for $1\frac{1}{2}$-, $1\frac{1}{4}$- and 1-in. branches and, in the case of the 4- and 3-in. pipe, for $1\frac{1}{4}$- and 1-in. branches.

The saddles can be used with either ABS or high-impact PVC pipes.

Dual laminate

In chemical plant fabrication a laminate of *Cobex* (rigid PVC) and *Velbex* (plasticised PVC) is often used, and a further special form of *Cobex* is reinforced with expanded metal, thus extending its usefulness up to and even above 100°C. Corrugated *Cobex* for roof lights or construction is available in sheets to match standard roofing sheets, and this material was used to clad a 65-ft. tower erected at the chemical works of F. W. Berk & Co. Ltd., Stratford, London, which houses a difficult and highly corrosive remote-controlled chemical process.

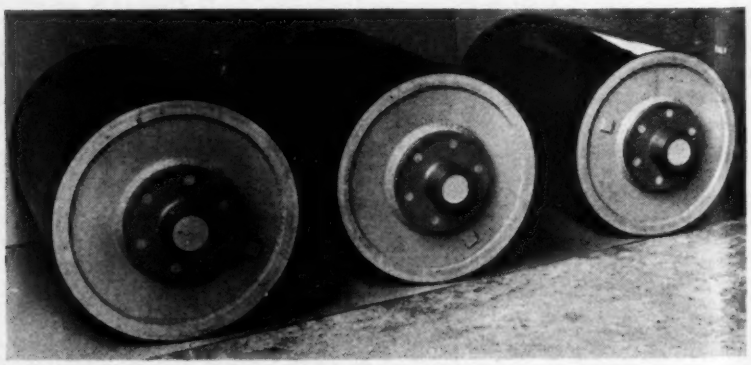
A large part of the fume exhaust ducting installed at the National Chemical Laboratory, Teddington, is also made from *Cobex*.

Pastes for spray coating

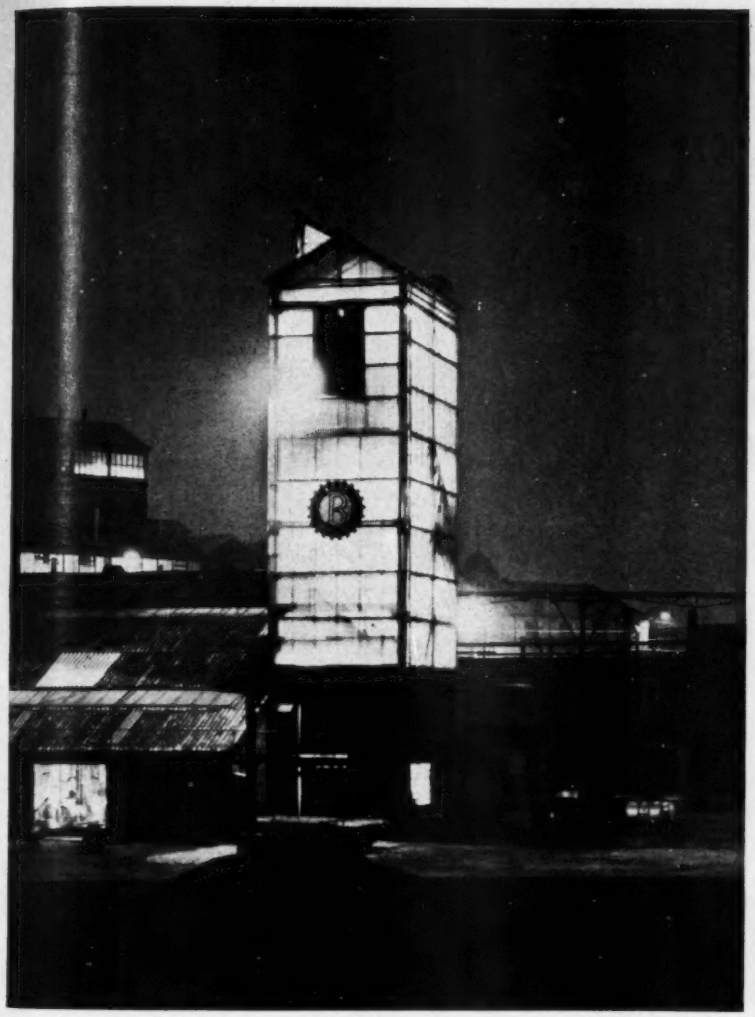
Although PVC pastes have been used very successfully for many years as protective coatings they have, until recently, been suitable for application only by dip coating, shrunk-on techniques and sheet bonding.

Recent development has led to the introduction of a new range of Vinatex Ltd. pastes designed for spraying. These pastes give coatings which are said to have good abrasion resistance, be tough and flexible and not to crack or chip. The makers state they are suitable for use on mild steel, stainless steel, chromium plate, tin plate, aluminium and glass, and can be used, with suitable precautions, over galvanised sheet, brass or copper. The coatings obtained do not adhere to the substrate unless a suitable adhesive is used; however, if the coating envelops the article, lack of adhesion may not be of importance.

Since ovens similar to those used for stoving finishes are suitable for curing the Vinatex PSP 80 series, it



24-in. diam. PVC ducking-rollers for stainless-steel strip pickling.



A night view of the 65-ft. tower erected at the chemical works of F. W. Berk & Co. Ltd. to house a difficult remote-controlled chemical process. The tower is made of a steel angle frame with an outer sheet of corrugated transparent 'Cobex'.

now becomes possible for metal finishers who are not equipped with dipping tanks to coat articles with PVC. It is expected that PVC spraying pastes will be used mainly for coating large plane surfaces, such as ductings, which cannot be coated by dipping without the risk of runs and sagging.

The material of construction for chemical plant which will be discussed in next month's issue of CHEMICAL & PROCESS ENGINEERING will be

LEAD

THERMOPLASTIC PIPE SYSTEMS

(*Concluded from page* 198)

likes to have wide safety margins and long-term experience of the materials he is going to use. From this point of view both ABS and high-impact PVC pipe systems offer very considerable fields for exploitation within the industry, and their usage is increasing in this country and overseas at an astonishing speed.

Information and data for this article were supplied by: Mr. R. L. H. Damerham, B.SC., of Durapipe & Fittings Ltd.; British Geon Ltd.; I.C.I. Ltd. (Plastics Division).

REFERENCES

[1] J. A. Rhys, 'Plastics for Chemical Plant,' CHEMICAL & PROCESS ENGINEERING, 1960, **41** (4), 135.

CORRESPONDENCE

SIR,

I read with great interest the article by L. Cohen, November 1959. There is, however, one method of particle sizing which was not mentioned in this article. This method has the advantage of being rapid and accurate. It is a non-optical method, giving direct measurement of particle volume, unlike any other system, in the range ½ to 200 microns.

This involves drawing a suspension of particles in a suitable electrolyte (*e.g.* 0.9% saline) through a small orifice. Electrodes are placed at either side of this orifice and an electric current passed through. Changes in current due to the passage of a particle through the orifice produce short pulses whose amplitudes are proportional to particle volume.

A threshold, above which amplitude pulses will be counted, can be varied in steps to provide a size distribution analysis. Complete analysis can be performed on any sample by unskilled personnel in about 10 min. but a single count of number of particles above a given size can be made in 15 sec. A maximum of 150,000 particles may be counted in this time.

M. I. HENDERSON
Coulter Electronics Ltd.,
*London, W.*14.

SIR,

Your editorial comment in April, 'What's in a name?' discusses the problems facing chemical engineers in Britain only. It may not be sufficiently appreciated that chemical engineering as a technology and science is a purely Anglo-Saxon invention, existing as a separate entity only in the U.S.A., Great Britain and the Netherlands. In most other countries, and here I am particularly thinking of France, the term chemical engineer (*ingenieur chimiste*) only means chemical technologist or industrial chemist. This is a most confusing state of affairs and is not properly appreciated by chemical engineers in Britain. Naturally with the growing activities of British and American chemical and petroleum companies all over the world, chemical engineering in the Anglo-American sense is being propagated and applied. However, I do feel that much of this confusion could be prevented if chemical engineers at international conferences fundamentally discussed the problem that you have mentioned.

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Paris, X.

CPE Diary

MAY 10 TO 13 Symposium on **fuel element fabrication with special emphasis on cladding materials** in Vienna. Organised by the International Atomic Energy Agency. Details from I.A.E.A., 11 Karntner Ring, Vienna 1, Austria.

MAY 11 Conference on the **application of standards in industry** at the Connaught Rooms, Great Queen Street, London, W.C.2. Organised by the British Standards Institution jointly with the Institution of Production Engineers. Information from the Secretariat, I.P.E./B.S.I. Committee, British Standards House, 2 Park Street, London, W.1.

MAY 23 TO JUNE 1 **First plenary session of ISO/TC/85 on nuclear energy** and current sessions of subcommittees 1, 2, 3 and 4 in Geneva. Organised by the General Secretariat of the International Organization for Standardization. Details from H. G. Lamb, American Standards Association, 70 East Street, New York 17.

MAY 25 TO 26 Industrial convention on the role played by **nylon in industry** at Park House, London. Details from the organisers, British Nylon Spinners Ltd., 68 Knightsbridge, London, S.W.1.

MAY 29 TO JUNE 11 Special meeting of **Iron and Steel Institute,** including a joint meeting with the Associazione Italiana di Metallurgia, in Italy. Details from H. Cleere, Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1.

MAY 30 TO JUNE 2 First International **Pipes and Pipelines** Exhibition at Earls Court, London, S.W.5. Details from the organisers, Scientific Surveys Ltd., 97 Old Brompton Road, London, S.W.7.

MAY 30 TO JUNE 3 Jubilee conference of the Textile Institute on **fibre science.** Details from the institute, 10 Blackfriars Street, Manchester 3.

MAY 31 TO JUNE 3 Meeting of the Society of Physical Chemistry on the **structure of graphite and kinetics of its reactions** in Paris. Details from G. Emschwiller, secretary general, Society of Physical Chemistry, 10 Rue Vauquelin, Paris 5e, France.

JUNE 2 Jubilee dinner of the **Textile Institute** at the Dorchester Hotel, Park Lane, London, W.1. The Duke of Edinburgh will be the guest of honour. Details from the Textile Institute, 10 Blackfriars Street, Manchester 3.

JUNE 5 TO 9 World Power Conference —sectional meeting on the **methods for solving power shortage problems including conventional nuclear sources** in Madrid, Spain. Details from the secretary, British National Committee, World Power Conference, 201-202 Grand Buildings, Trafalgar Square, London, W.C.2.

JUNE 12 TO 16 Annual meeting of the **American Nuclear Society** in Chicago, U.S.A. Details from the secretary, Mr. O. Du Temple, c/o John Crerar Library, 86 East Randolph Street, Chicago, Illinois.

JUNE 14 TO 16 Annual meeting of the **Dechema** Deutsche Gesellschaft für chemisches Apparatewesen eV. and the 26th meeting of the **European Federation of Chemical Engineering** and the eighth meeting of the **European Federation of Corrosion** in the Palmgarten at Frankfurt. Details from the Dechema, Frankfurt (Main), Postfach.

JUNE 15 TO 29 International **Nuclear Congress and Exhibition on Electronics and Atomic Energy** in Rome. Organised by the Italian National Committee for Nuclear Research. Details from secretariat, Rassegna Elettronica, Nucleare e della Cinematografia, Via della Scrofa 14, Rome, Italy.

JUNE 27 TO JULY 8 International **course, in French, on nuclear energy,** designed for senior engineers and technical industrialists, at the Centre d'Etudes Nucleaires at Saclay, France. Details from O.E.E.C. European Nuclear Energy Agency, 38 Boulevard Suchet, Paris 16.

JULY 4 TO 5 International **congress on catalysis** in Paris at Maison de la Chimie. Organised jointly by International Congress on Catalysis Inc., a French national committee which acts as host, and the International Union of Pure and Applied Chemistry. Information from Dr. H. Heinemann, c/o M. W. Kellogg Co., 711 Third Avenue, New York, N.Y., U.S.A.

JULY 4 TO 8 Gordon research conference on **chemistry and physics of isotopes** at the New Hampton School, New Hampton, New Hampshire, U.S.A. Organised by the American Association for the Advancement of Science. Information from Dr. W. C. Parks, director, Department of Chemistry, University of Rhode Island, U.S.A.

JULY 4 TO 15 International course, in English, on **nuclear energy designed for senior engineers and technical industrialists** at A.E.R.E., Harwell. Information from O.E.E.C., European Nuclear Energy Agency, 38 Boulevard Souchet, Paris 16.

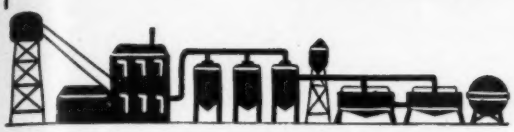
JULY 18 TO 26 **Tercentenary celebrations of the Royal Society.** Ceremony in the Royal Albert Hall on July 19. Other activities include lectures and a conversazione at Burlington House. Information from Mr. M. Whitchurch, press officer, tercentenary celebrations, I.C.I. Ltd., Millbank, London, S.W.1.

JULY 21 TO 30 International **Nuclear Power Exhibition** at Earls Court, London. Information from the organisers, Nuclear Power Exhibition Ltd., Francis House, Francis Street, London, S.W.1.

JULY 25 TO AUGUST 6 General Assembly of the International Union of Geodesey and Geophysics including symposium on **atmospheric chemistry and radioactivity** and symposium on **dynamical processes in the atmosphere,** to be held in Helsinki, Finland. Information from the organising committee for the assembly, c/o Institut Geodesique, Bulevardi 40, Helsinki, Finland.

JULY TO AUGUST Symposium on **technical and industrial applications of nuclear energy, including reactor technology and the economics of nuclear energy.** To take place in Brazil. Organised by the Inter-American Nuclear Energy Commission. Details from the executive secretary of the commission, c/o P.A.U., Washington 6, D.C., U.S.A.

WHAT'S NEW



Plant • Equipment • Materials • Processes

CPE reference numbers are appended to all items appearing in these pages to make it easy for readers to obtain quickly, and free of charge, full details of any equipment, machinery, materials, processes, etc., in which they are interested. Simply fill in the top postcard attached, giving the appropriate reference number(s), and post it.

Synthetic rubber

A new type temperature-resistant synthetic rubber, *Viton*, has been introduced by Du Pont Co. (U.K.) Ltd. Tests at 500 to 600°F. show that useful elasticity is retained up to twice as long as with other elastomers. Resistance to special lubricants and hydraulic fluids used in missiles and high-speed aircraft is said to be improved in the presence of such chemicals as red fuming nitric acid and glacial acetic acid. It can be used for moulded goods and coated fabrics. **CPE 1489**

Tanning drum

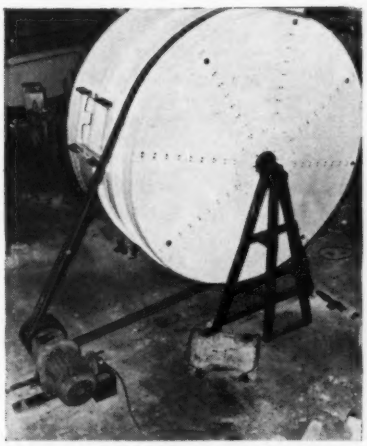
The corrosive nature of some chemicals used in the leather processing industry narrows the choice of material for tanning equipment. Timber has been in use for many years and has proved a satisfactory material for many purposes. When tanning drums are used for dyeing, however, the timber becomes impregnated with dye and one drum can, therefore, only be used for a strictly limited range of colours.

In order to overcome this problem Turner Machinery Ltd. have recently built an experimental glass-fibre-reinforced polyester tanning drum which, because it can be so easily washed out, can accept different colours. This is at present undergoing trials in a tannery. **CPE 1490**

Muffle furnace

A new bench model, all-purpose, muffle furnace is offered by the allied engineering division of Ferro Enamels Ltd. to meet the demand of industry for a unit for temperatures up to 1,000°C.

The working chamber consists of a nichrome-wound muffle forming an interchangeable independent unit.



This drum is 8 ft. diam. × 4 ft. wide and is capable of carrying loads up to 3 tons revolving at a speed of 16 r.p.m. It has been contact-moulded in two parts on male moulds using 'Crystic' polyester resin supplied by Scott Bader & Co. Ltd., 'Duramat' chopped-strand glass mat by Turner Brothers Asbestos Ltd. and one layer of woven-glass cloth supplied by Fothergill & Harvey Ltd.

An adequate quantity of insulation surrounds the muffle to ensure low heat dissipation to the outside casing. The casing is of all-welded, sheet-metal construction with the exception of the top section whereby access is obtained to the muffle. A guillotine-type door operating on a chain-and-pinion mechanism and counter-balanced for ease of movement forms an effective heat seal to the muffle opening. Control is effected by an infinitely variable energy regulator operating through a contactor relay. The furnace is also available with fully automatic control.

Signal lights are provided in the circuit indicating electric supply to the kiln and position of contactor. A safety switch in the circuit also breaks the supply when the door is opened.

The furnace operates off standard single-phase electricity supplies, is normally rated at 2.75 at 230 v. and reaches 800°C. in 2 hr. Temperature uniformity is stated to be within 5°C. from the front to the rear of the muffle. **CPE 1491**

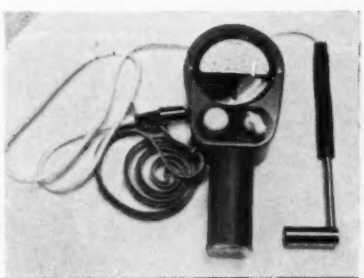
Measuring temperature in hazardous areas

A new, explosion-proof, coarse temperature controller, which is suitable for use in hazardous and flame areas, is the *Stratotherm* energy regulator, offered by the Stabilag Co. Ltd.

The unit is designed to take a maximum loading of 2 kw. and can be used on a 220 to 230 v. supply; it regulates to infinity the electrical input between 10 and 100% of the rated consumption. The mean heating output achieved with the regulator is obtained by intermittent operation corresponding to the time for which the controlled appliance is switched on and off. **CPE 1492**

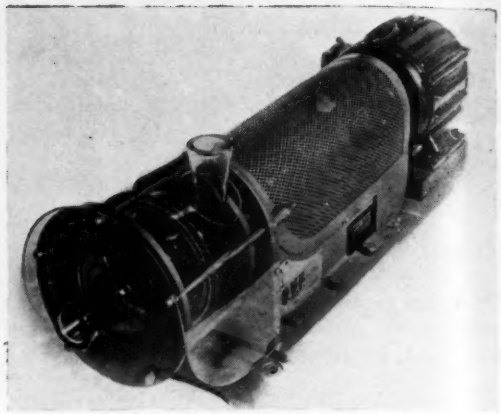
Air velocity meter

An air velocity meter has been jointly developed by Gelman Instrument Co. of U.S.A. and Wallac Co., Finland. It is claimed that the new device measures accurately air speeds from 0.05 to 30 ft./sec. It also



Air velocity meter.

measures air temperatures in two ranges: 30 to 110°F. and 50 to 250°F. The *Thermo-anemometer* is composed of a directly calibrated meter-power unit small enough to hold in use. The battery power is from a standard flashlight battery contained in the handle. The probe consists of a small metal cylinder in which two resistance wires are mounted. One of the wires is heated, the other cold. The two elements are arranged in a wheatstone bridge circuit so that the cooling effect is a function of air velocity. Air temperatures can also be tested by flipping a switch to change from velocity to either of two temperature scales. **CPE 1493**



All-glass pump for dealing with corrosive liquids.

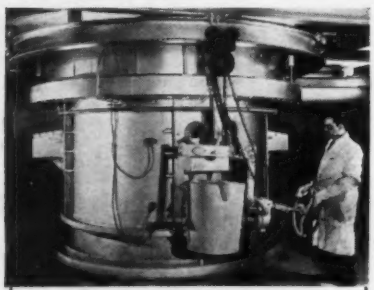
All-glass pumps

Two all-glass pumps for dealing with corrosive liquids are offered by Q.V.F. Ltd.

Both pumps are of the centrifugal type, running at medium speed. The glass impeller is of simple design based on a vortex-type inlet with specially designed arms.

The mechanical seal is a glass-loaded *Fluon* bellows rotating on a glass plate and a specially designed bearing chuck holds the precision-ground impeller shaft.

Models GPA/6 and GPA/9 are both mounted on heavy cast-iron base plates and both pumps require priming. The former is operated by a 1-h.p., four-pole, three-phase motor and the latter by a 3-h.p., four-pole, three-phase motor. **CPE 1495**



ELECTRIC SMELTING 'ON APPROVAL'

A scheme that it is hoped will assist rapidly developing countries to exploit their mineral resources has been devised by Birlec-Efco (Melting) Ltd.

A Birlefco *pilot furnace has been built to test mineral ores, on a contract basis, for their amenability to electric smelting. Particularly where hydro-electric resources are available, the electric smelting process can economically be used for the extraction from their ores of nickel, copper, manganese, iron, ferro-alloys, and other materials. Trial batches of ore will be accepted from any part of the world for testing on a miniature scale in the furnace. On completion of the test, a detailed report will be submitted, giving recommendations on smelting practice, electrical ratings and size of full-scale installation required for a given output.* **CPE 1494**

Coming to a sticky end

The use of pumping equipment in the manufacture and processing of adhesive materials has presented a variety of problems to pump manufacturers and users. The most serious problem is the tendency of pumps to seize-up with hardened adhesive during shut-down periods, causing damage to pump parts when operations are resumed.

Further difficulties are encountered by use of pumps which break up the adhesive material and cause liquid separation through centrifugal action, thereby upsetting the balance of the adhesive formula. The physical properties of highly viscous adhesive materials can also be upset when rapid agitation takes place within the pump or when cavitation or 'squashing' of the adhesive occurs. This can cause lumpiness and affect other essential characteristics of the adhesive.

Fill in and post the reply-paid card for details of any items in these pages, making sure to quote the correct 'CPE' reference number.

Recently National Adhesives Ltd. were faced with a problem of pumping polyvinyl acetate emulsion of 12,000 sec. viscosity from portable storage vessels into large processing vats. The requirement was for a lightweight portable pump unit which could handle 2,000 gal./hr. of PVA emulsion, approximately 55% solids at 20-ft. heads without agitation or centrifugal action. The pump chosen was a *Goodyear* size 7 positive displacement pump which employs bonded elastomer-to-metal parts to reduce wear and provide sealing between moving components. The increased solidification during shut-down periods was overcome by manually turning the rotor before starting the electric prime mover. The axial flow action of the pump did not agitate the liquid harmfully.

The pump, manufactured by Goodyear Pumps Ltd. in bronze with a stainless-steel rotor, has low weight, ease of maintenance and only two moving parts in contact with the liquid. **CPE 1496**

Descaler

A new descaler designed for smaller industrial applications is *Calgon*, an inhibited acid in powder form which is said to be easily handled and used with safety to remove scale from cooling towers, condensers, small boilers and heat exchangers. Other features are its non-foaming properties and the absence of fumes.

The inhibitors in the descaler have been designed to protect steel, copper, brass and aluminium surfaces. Provided copper corrosion products are absent, the descaler is said to be safe in contact with galvanised surfaces.

It contains an acidity indicator which shows when the active constituent is exhausted. The colour changes from green to purple when the descaler is almost neutralised. **CPE 1497**

Precision temperature controller

A precision temperature controller with a differential of 0.5°C. is offered by Fielden Electronics Ltd. The meter-type case is completely sealed and contains no delicate moving parts and the instrument can be mounted at any angle.

Control can be at any temperature between −200 and +500°C. with a minimum temperature range span of 50°C. and there are 12 standard calibrations in °C. and °F.

A platinum resistance element is used at the temperature measuring point, this being housed in a stainless-steel sheath of ¼-in. diam. Ordinary connecting cable is used between the measuring point and the instrument. The makers say that this can be up to 300 ft. long without inducing errors.

The control action is on/off, either electrical or pneumatic. The electrical contacts give changeover switching at 5 amp. and 250 v. while the pneumatic valve requires 17 to 20 p.s.i. input.

CPE 1498

Elevator for smalls

A high-speed screw elevator, which has been designed primarily for handling boiler-house smalls where for one reason or another it is not convenient or possible to prepare a concrete ground hopper or pit, is offered by Hodgkinson (Salford) Ltd. It is said to be ideal for feeding the hoppers of *Low Ram* chain grate or underfeed stokers.

The elevator consists of a steel tube in which rotates a worm housed in totally sealed, self-aligning ball bearings and driven by a constant-speed, totally enclosed motor mounted on a platform at the head of the casing. A short standard chute extends from the head to which an additional section or breeches piece can be added, provision being made for this to be swivelled to suit site conditions. At the tail the worm is exposed for the entry of coal. An adjustable device enables the head to be supported from any convenient structure in the boiler house.

Each unit will handle up to 15 tons/hr. of smalls and feed direct to the stoker simply by resting the tail on a pile of coal and lifting the head into position over the stoker hopper. The elevator is self-cleaning and no running maintenance is required since the bearings are grease packed and sealed.

The machine is available in six standard lengths. **CPE 1499**

Butterfly valve for high-vacuum work

Although the 'butterfly' valve is used extensively for general engineering purposes, it has never been adapted for high-vacuum work because of the difficulty in obtaining a vacuum seal around a plate periphery. This problem is claimed to have been overcome in the *Speedivac* QSB series of quarter swing 'butterfly' plate valves, made by Edwards High Vacuum Ltd., resulting in a compact 'in-line' high-conductance valve, capable of resisting pressure differential in either direction.

The valves are constructed in stainless steel and the whole range consists of a small 1-in.-bore version and larger 2, 4 and 6-in.-bore models. The former, the QSB1, can only be supplied for manual operation, but the QSB2, QSB4 and QSB6 are available either as manual or pneumatically operated valves. The latter are used where the vacuum system has to be remote or automatically controlled. For pneumatic operation, a double-action, pneumatic driving cylinder is fitted to the valve shaft and secured to the valve body by a trunnion bracket.

CPE 1500

PVC sheeting

A thermoplastic rigid sheet material developed to meet the need for a PVC sheet combining toughness with vacuum-forming properties is *Vybak DVR* 262. The material represents a new approach to the formulation of high-impact-strength PVC sheet, in that it is produced entirely from PVC co-polymers. It contains small quantities of stabilisers, lubricant and pigment but no plasticisers, and the use of modifiers, which often lead to poor ageing characteristics, is therefore avoided.

It is claimed to have good dimensional stability and to be capable of deep draw with good detail. Its toughness and deep drawing characteristics allows its use in many applications such as refrigerator liners, trays, industrial containers and other formed shapes.

The sheet, which is made by Bakelite Ltd., is not recommended for applications in which resistance to temperature in excess of 50°C. (122°F.) is required. **CPE 1501**

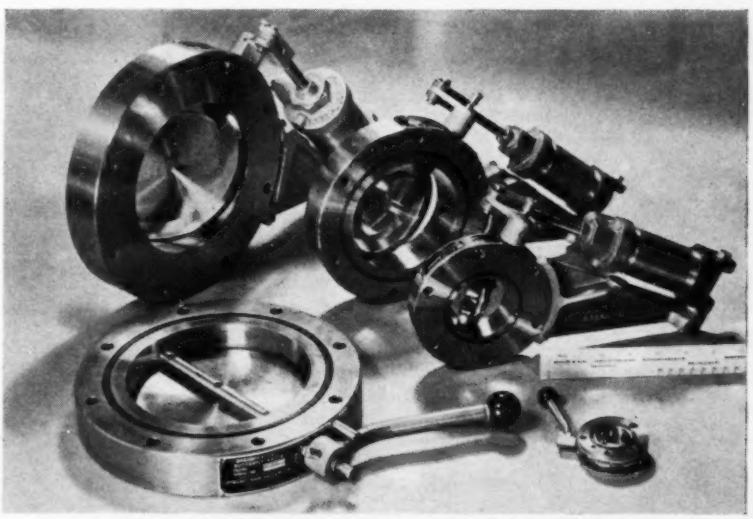
High-vacuum pump

A pump, designed to give users the advantage of obtaining high vacuum from a fully automatic pumping unit having single-lever operation control, is offered by N.G.N. Electrical Ltd.

In the event of accidental stoppage or power failure, the unit is automatically isolated, thus damage cannot be caused to the plant or apparatus in the vessel being evacuated.

If the cooling water to the diffusion pump is inadvertently cut off a red light indication is given to the operator and the heater to the diffusion pump is automatically shut down.

The operating handle has four positions—rough pump, fine pump, isolation and air admittance—a quadrant movement separating these four posi-



Hand- and pneumatic-operated 'Speedivac' butterfly valves.

tions. When the unit is set on rough pump, the vessel being evacuated is pumped down to approximately 350 microns before fine pump selection occurs, which brings the diffusion pump into circuit; at this setting the rotary pump acts as the backing pump.

The isolation position of the lever isolates both pumps from the vessel and on air admittance a magnetic valve is actuated, permitting air to enter the evacuated vessel.

The unit is now ready for another cycle of operations. It is not necessary to operate the handle in the full cycle of movement since it can be turned clockwise or anti-clockwise through 180° in one movement, *i.e.* from rough pump to isolation, without harming the unit or apparatus.

All detachable joints are made with *Nygon* 'O' rings and provision is made in the unit for a gauge head fixing. Two sizes of unit are available, being designed to give an ultimate of better than 5×10^{-6} mm. Hg, with pumping speed better than 23 l./sec. or 100 l./sec., at a pressure of 1×10^{-4} mm. Hg.

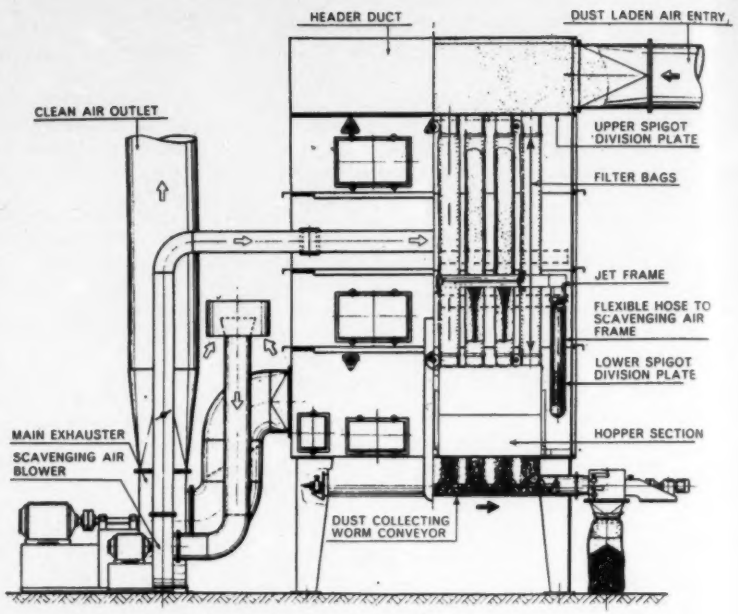
The diffusion pumps are of the fractionating type and the backing pumps are gas ballasted to allow the evacuation of chambers containing condensible vapours. **CPE 1502**

High dust burden and adhesive dust filter

An addition to the range of dust collection and control plant manufactured by the gas cleaning division of W. C. Holmes & Co. Ltd. is the *Holmes-Retroflux* bag filter. It was developed by Standard Filterbau GmbH. of Munster and is to be manufactured under licence in the U.K.

The bag filter is said to be particularly suitable for those applications where high dust burdens are encountered and/or dusts of an adhesive nature have to be collected. An efficiency in excess of 99% for all particles, including those of submicron size, is claimed.

The dust-laden air enters the header within the casing and is distributed within the inside of the filter bags, the air and dust moving in the same direction. The tendency of the dust to settle by gravity is not impeded by air currents as the air passes through the filter bags radially and the air velocity gradually diminishes to zero at their lowest end. The dust collected on the inner surface of the filter bags is continuously dislodged by the passage of high-velocity air jets through the fabric in the reverse direction to the main air stream. The dislodged dust falls by gravity to the worm conveyor or hopper below. The use of high-velocity air jets dispenses with the rapping or shaking mechanism and separate compartments.



A general arrangement drawing of a Holmes-Retroflux bag filler.

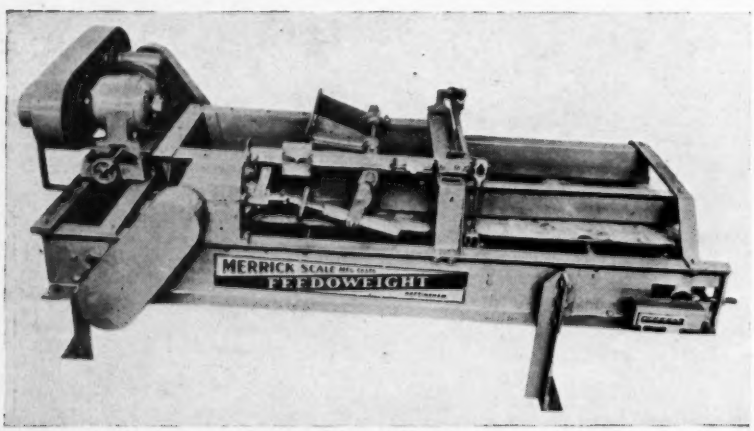
An advantage claimed for the bag filter is that each filter bag is continuously and efficiently cleaned over its entire surface area. **CPE 1503**

Constant-weight feeder

A constant-weight feeder capable of accurate performance in dealing with almost all classes of bulk materials from powders to lumps, said to be suited for ensuring accurate feed of a single material or when used in multiples for material proportioning and blending, is offered by Merrick Scale Mfg. Co. Ltd.

A tachometer generator and indicator can be fitted which enables the operator to pre-set output over its entire capacity range. Controls and belt speed change may be effected from the remote position.

To provide a permanent continuous record of output an electrically operated continuous strip chart recorder, operating in conjunction with a frequency-responsive tachometer generator, is available or a circular chart recorder operating from an electrical contactor device and marked on the master weight totaliser can be fitted. **CPE 1504**



Constant-weight feeder.

What can be Patented?

By Lord Meston

To most scientists and engineers the workings of the Patent Office must often seem abstruse and complicated. Industry, one is informed, could not survive but for the safeguards afforded by a valid patent. Yet, how many people really know what can be patented? To understand that fully a legally valid definition of a process and method of invention must be given; this is not always coincident with the accepted definition. In this article the well-known legal authority, Lord Meston, explains the legal requirements of taking out a patent and especially what constitutes a method of manufacture. Interesting examples of patentable and non-patentable processes are included, and mention is made of a case involving patent infringement.

IN other words, what can be the subject matter of a patent? The answer is that this must be an invention, which is defined in the Patents Act, 1949, as 'any manner of new manufacture the subject of letters patent and grant of privilege within Section 6 of the Statute of Monopolies, and any new method or process of testing applicable to the improvement or control of manufacture, and includes an alleged invention'.

By long usage 'manner of manufacture' has come to include not only articles and substances produced by manufacture, but also manufacturing processes. Machinery and factory equipment generally are included, as themselves manufactured things.

'Manufacture' connotes first of all the making of something. It is seldom that there can be a process of manufacture unless there is a 'vendible product' of the process, something useful for its own sake and vendible as such.

What is meant by a 'vendible product'? This term is not to be found in any Act of Parliament but has become part of the law and practice of patents. At first sight, the word 'vendible' refers in some way to a sale or the capacity for being sold. But that is not really the dominant meaning of the term in the present sense. 'Vendible product' in reference to the result of manufacture lays emphasis upon the trading or industrial character of the process. A manner of manufacture in its ordinary sense imparts the idea of making 'something'; and by 'something' is commonly understood something tangible and material. Therefore, the term 'vendible product' does not cover something which is academic and intangible as, for example, a method of diagnosing a disease.

Methods and processes

Methods and processes are in a different category from articles and apparatus. An article or apparatus is prima facie a manufacture, but a method or process is not a manufacture unless it results in the production of some tangible vendible product. There are many ingenious methods or processes which result in no vendible product and are accordingly incapable of protection by patent. One might instance methods of diagnosing or treating diseases, methods of chemical or physical testing, methods of detecting hostile aircraft, and so forth. Likewise a method of extinguishing incendiary bombs falls within the category of methods which are inherently incapable of protection by patent. If a person puts out an incendiary bomb, whether by means of sand, water, zinc chloride solution, or any other means, he is performing his civic duty, but certainly not conducting any manufacture.

A method or process is a manner of manufacturing if it (*a*) results in the production of some vendible product, (*b*) improves or restores to its former condition a vendible product or (*c*) has the effect of preserving from deterioration some vendible product to which it is applied.

The general meaning of the term 'product' is capable of considerable extension. Thus a patent has been granted for a method of protecting subsoil against subterranean fires—protected soil being regard in some sense as a 'product'.

Furthermore, the term 'product' here may include things that are not 'articles' and things that are evanescent. Thus patents may be granted on the basis that electricity is a 'vendible product'.

Methods of working sources of power other than electric generators are patentable. For example, methods of working internal combustion engines may constitute valid claims for patents. The general practice of the Patent Office is to accept claims for new methods of working any apparatus that would itself, if new, be patentable, provided the novelty in the method is substantial and is mechanical in character.

Discovery and invention

A mere discovery is not the proper subject matter for a patent. The distinction between a discovery and an invention is that discovery adds to the amount of human knowledge, but it does so only by disclosing something, while invention also adds to human knowledge, but not merely by disclosing something. Invention necessarily involves also the suggestion of an act to be done, and it must be an act which results in a new product, or a new result, or a new process, or a new combination for producing an old product or an old result.

Information

Mere information is not a ' product ' in the sense we are discussing. Nor is every process that produces something vendible an invention. Manufacture connotes the sort of thing that is done in a factory and not, for instance, agricultural or horticultural operations. Therefore, a claim for a patent has been refused in connection with pruning and protecting the raw surfaces of clove trees with good sterilising dressing to prevent the entry of fungi. The ground of the refusal was that a fruit tree is not a product in the present sense. New strains of living creatures, animal or vegetable, are not patentable, nor are ways of producing them. On the other hand, microbiological methods of manufacturing chemical substances are as patentable as any other manufacturing methods.

A few practical examples may be useful. Patents have been refused for the use of a known substance as a fertiliser, as a weedkiller and as an insecticide, and also for a method of fumigating buildings by spraying with a known substance.

On the other hand, patents are habitually granted for methods of permanent waving. Some patents have been granted for improvements in the manufacture of substances such as penicillin, the improvement lying only in the technique of growing the living organism concerned. A patent has been granted for a method of manufacturing chemicals by fermentation, the only novelty lying in the way of selecting the bacteria for the fermentation and in the resulting higher yields.

'Alleged invention'

As to there being an ' alleged invention', the position is as follows: To be an ' invention ' there must be not only a manner of manufacture or method of testing, but one that is new or is alleged to be new. That is to say, there must be novelty alleged which is mechanical in character, which is possessed by the article or process in its capacity of a manufacture.

Therefore, a patent can be refused where the only material product is a printed sheet, tickets, coupon or its equivalent, and the only alleged invention an arrangement of words or the like upon such sheet, the new arrangement serving no mechanical purpose.

A patent will not be granted for a ' mere scheme or plan ' as distinct from a new arrangement of apparatus for putting the scheme into effect. On this ground, the following have been held to be unpatentable—a new system for arranging houses in a row; the colouring of fertilisers to aid in distinguishing them; systems of naval tactics or military camouflage.

It is not an ' invention ' merely to make an article from a substance that is known to be suitable for making it but which happens never to have been used for it before.

There is a general rule to the effect that a patent cannot be granted for a 'mere new use of an old thing'. But the strict application of that rule has been sometimes relaxed. For example, patents have been granted in respect of a motor-car windscreen made of toughened glass, and a copper container for a known process used under conditions where its behaviour could not be predicted and resulting in improvement in working.

If the subject matter of a claim for a patent must inevitably be too wide, it is not patentable. The ordinary example of this type of case is a claim to any method of performing a known manufacturing operation automatically.

Manner of manufacture

As we have noted, an invention to be patentable must include some 'manner of manufacture'. It is within the province of the Comptroller of Patents to decide whether the subject of an application for a patent is a 'manner of manufacture', so that it is unlikely that any invention which did not satisfy this requirement would ever become the subject of a granted patent. There is in fact no reported case in which a patent has been held invalid merely on the grounds that the invention claimed was not a manner of manufacture. Therefore, in an action for infringement of a patent it is extremely unlikely that the defendant can raise by way of defence that the plaintiff's invention is not patentable because it does not involve a manner of manufacture. That very point was decided by the Comptroller of Patents when the plaintiff or his predecessor in title made the application for the patent to be granted to him in the first instance.

Novelty

However, different considerations apply when we consider the question of 'novelty'. In an action for an infringement of a patent, the defendant may raise, by way of defence, a plea that ' the invention is not new having regard to what was known or used in the United Kingdom'. In other words, has there been some ' prior use ' of the alleged invention before the plaintiff obtained the grant of a patent for that invention? A celebrated case on this point was the Gillette Safety Razor Co. *v.* the Anglo-American Trading Co. Ltd. A patent had been granted for ' Improvements in or relating to safety and other razors'. In an action for infringement of the patent the defendants denied infringement and alleged that the patent was invalid for want of novelty and of subject matter. The subject matter of the patent was ' a safety razor comprising a thin flexible blade detachably combined with a holder by which the blade is positioned and supported and its cutting edge is given the rigidity necessary to make it operative for shaving'.

The evidence showed that a similar device had been in use before the patent in question was granted to the plaintiff. The result was that the defendants were not liable.

Uranium processing

Mallinckrodt Nuclear Corporation, one of the largest commercial processors of uranium fuels, is adding 3,200 sq. ft. to its nuclear fuels research facility at the Hematite, U.S.A., plant. The corporation is at the same time building a new atomic fuels warehouse to replace the space taken over by the growing research and development activities.

This expansion, the third since the plant was built in 1956, brings the total space to two and a half times the original, or 40,000 sq. ft., devoted to commercial production of atomic fuels for research reactors, critical facilities, power reactors and process heat reactors.

Limestone production

Powell Duffryn Ltd. has acquired the whole of the share capital of Kelmac Ltd., a company which owns a limestone quarry at Nether Kellet, and produces a range of high-grade limestone products, including dry and wet mixed graded limestone for road works, bituminous and tarred macadam, concrete aggregate, and material for the manufacture of chemical fertiliser.

A modern crushing and processing plant capable of supplying material to the highest current specification for road construction and maintenance is installed.

Mr. R. Hopwood is chairman of the company.

Company News

Detergent raw materials

Marchon Products Ltd., a member of the Albright & Wilson group, are proceeding with plans for the manufacture of detergent raw materials in Northern Italy by their wholly owned subsidiary, Marchon Italiana.

The factory site is at Castiglione delle Stiviere, about 80 miles east of Milan, and it is anticipated that the plant will be completed by the end of the year.

Silicon

High-quality silicon is to be made in Great Britain by Monsanto Chemicals Ltd. This development is the result of an agreement with the Siemens Cos. of West Germany, originators of the manufacturing process which Monsanto is to operate at its Ruabon, North Wales, factory. Production will begin in the last quarter of 1960.

Silicon of exceptionally high purity is used in the manufacture of power rectifiers and in transistors and other semi-conductor devices used in the electronics and electrical industries. Its properties at high operating temperatures are making it an increasingly attractive alternative to germanium.

Colloid mills

Premier Colloid Mills Ltd. have recently completed the erection of extensions to their main offices and laboratories at Walton-on-Thames. These extensions have been planned to centralise the assembly of colloid mills and mixers which they manufacture for many industries such as paint, petroleum, food and cosmetics.

Design and development

The Gas Council is to establish a development and planning section to be responsible for the design and development to full-scale size of new production processes, including those discovered at the research stations of the council.

The section will also be responsible for preparing plans on a national basis for an integrated supply system which is the logical development of the policies of integration and concentration of production adopted by Area Gas Boards.

It is hoped that the new proposal will ensure continuous contact between those responsible for research in the industry, and those responsible for commercial production.

Polypropylene

Rapid progress was made during 1959 on the erection of I.C.I.'s polypropylene (*Propathene*) plant at Wilton. Reports from the chemical engineers engaged on this job indicate that this 10,000-ton-capacity plant will be on stream towards the end of this year. I.C.I. believe that the plant will be the first commercial-scale polypropylene plant to come into operation in this country. It is being built in a way that will allow for rapid expansion.

Alongside this plant the plastics division will produce organo-aluminium compounds in bulk for use as catalysts in the process. The production of these complex chemicals presents a number of technical difficulties, but the I.C.I. chemical engineers responsible for the development report excellent progress.

Hose fittings

Hozelock Ltd. have acquired the sole manufacturing and selling rights of the hose fittings previously manufactured by the engineering division of Airtech Ltd.

The purpose of this new company is to manufacture and market patent couplings and fittings for all types of rubber and plastic hose and tube. This follows the introduction last year of new plastic fittings for garden hose. The range of fittings is now extended to cover many other uses including farm water supplies and industrial uses. Later plans cover domestic water installations. The couplings are designed to fall in with the growing trend towards plastic tube in place of metal pipes.

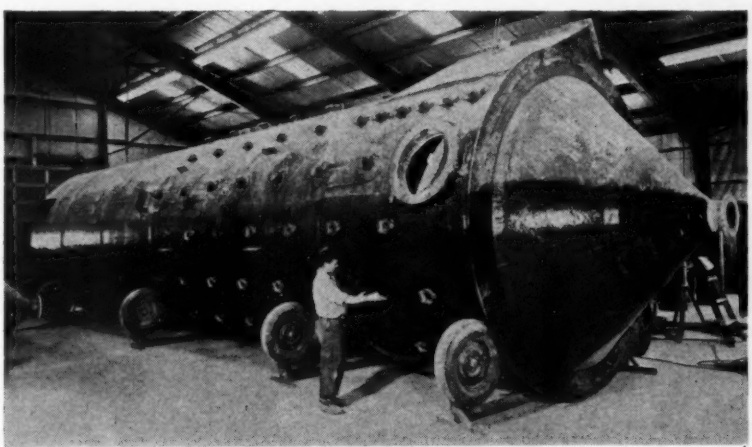
Sewage purification

Woodall-Duckham Construction Co. Ltd. has contracted to purchase the whole of the issued share capital of Ames Crosta Mills & Co. Ltd. for the cash sum of £735,000.

Ames Crosta Mills & Co. Ltd., which is well known in the field of sewage purification engineering, will continue to operate as an independent unit under its present board of directors within the Woodall-Duckham group of companies.

Headquarters transfer

Nobel division of I.C.I. Ltd. are to transfer their headquarters from Glasgow to Stevenston, near the company's Ardeer factory. Staff employed and resident in the Glasgow area will now require to transfer or travel to Ayrshire. The transfer will take place over a period of two years. A new office building is to be erected at Stevenston to give the division completely integrated administrative facilities alongside the production units.



FUME SCRUBBER

Believed to be the largest unit of industrial equipment ever fabricated from reinforced plastics, this chemical fume scrubber is made of Hetron(R) 92 *polyester resin produced by the Durez Plastics Division of Hooker Chemical Corporation. Shown here are conical section (at bottom of installation), individual spray nozzle connections, entrance and inspection ports, as well as mounting flange. The unit was designed and engineered by Buffalo Forge air-cleaning division and fabricated by du Verre Inc.*

New Books

Manufacture of Sulphuric Acid. Edited by Werner W. Duecker and James R. West. Reinhold Publishing Corporation, 1959. Pp. 515. 100s. net.

The preface to this monograph states that this originates from the standard work, 'Sulphuric Acid Manufacture,' by A. M. Fairlie, which, written in 1935, was never revised due to the death of the author.

A comparison with Fairlie demonstrates that this is, however, a completely new treatise in this field and, in fact, the only resemblance to the old Fairlie is that it is in the main a review of modern American practice in the field of sulphuric acid manufacture.

In the contact process, and using brimstone as a raw material for hot gas manufacture, there is little doubt that this is probably more advanced than standard British and Continental practice.

The only criticism for the British reader can be on this score: the critical sulphur shortage of the early fifties forced the expansion of the sulphuric acid industry in the U.K. into the use of raw materials very different from those in America; for example, sulphuric acid from indigenous anhydrite and, from sterling area pyrites, using either fluidised bed or flash roasters.

In addition, due to the widespread use of natural gas in America, there are only small tonnages of spent oxide, and it does not feature as a raw material for acid manufacture.

Recent alkali inspectors' reports seem to indicate that the trend in this country has followed that in the United States, in that the major expansion has been in the contact process at the expense of the old lead chamber plants, though due again to the difference in raw materials there has been some retention of manufacture in new units using accelerated chamber or tower processes, such as the Kachkaroff. Only the briefest reference will be found to these important items in the manufacture of sulphuric acid in this country.

In common with many similar American monographs, this book is now the collected work of 24 specialists in their respective fields and yet remains insufficiently detailed to merit the title of a monograph.

The chapter references are excellent and well selected from U.S.A., U.K. and Continental sources. The text is well prepared on excellent paper, is well illustrated and will no doubt be considered a 'must' for every sulphuric acid plant manager.

F. MOLYNEUX.

Reports on the Progress of Applied Chemistry. Vol. XLIII. Edited by H. S. Rooke. Society of Chemical Industry, London, 1958. Pp. 911. 100s. net.

To the ordinary works chemist or engineer the activities of the Society of Chemical Industry must often seem remote and awe-inspiring, not unlike those of other erudite societies to which so many professional people belong *pro forma*.

Such an impression is dispelled rapidly if one surveys the massive volume of 'Reports on the Progress of Applied Chemistry' which is published annually by the S.C.I. This can serve as a useful geiger counter to measure the rate of activity in practically every single sphere of industrial and applied chemistry.

The 1958 edition, published recently, is divided into eight chapters, which are subdivided into 41 smaller sections. The chapters deal with fuel and fuel products, organic chemistry, inorganic chemistry, metals, biological products, textiles, plastics, paints, chemical engineering and hazards (an unfortunate heading), agriculture and food.

These are the same chapters as in the 1957 edition. Interesting additions and omissions have, however, been made in the sections. Two new sections dealing with explosives and cosmetic and toilet preparations have been added to organic chemistry, whereas a new section on essential oils has been grouped into the agriculture and food chapter. This might surprise Ruszicka and Naves who have all their lives considered themselves as organic chemists. Both the sections on industrial gases and industrial uses of radioisotopes have been omitted altogether. This is rather surprising and unjustified.

The space allotted to the various sections is rather odd at first sight. Whereas 38 pages have been devoted to plastics and nine pages to rubber, only 13 pages have been allotted to basic chemical engineering which includes fluid-flow heat transfer and unit operations. It would seem to be nearly impossible to review over 2,000 chemical engineering papers in such a short space, yet it has been done. Several interesting and relevant items in this volume are briefly mentioned in this review. Rapid growth in irradiated polymers since 1948 is shown by the numerous publications that have appeared on an ever-increasing scale since then. Assiduous measurements of the physical properties of organic compounds have shown that they possess a surprisingly wide variation in radiation resistance. Radiation appears to be particularly effective in damaging highly crystalline polymers as for instance cellulose, PTFE and polypropylene. Mention is made of the fact that industrial interest in the beneficial uses of radiation was primarily stimulated by the potential availability of vast quantities of radioactive fission products. Paradoxically, the only commercially offered irradiated polymers have been made with electric machines such as Van de Graaf accelerators and resonant transformers. It is doubtful, however, whether radiation will find large-scale commercial use for the cross-linking or modification of other polymers besides polyethylene.

It is generally agreed that the most important event of recent years in the polymer field is the discovery by Natta and his Milan school of stereospecific polymers using polymerisation catalysts of the Ziegler type. These remarkable polymers can, however, only be obtained from one single monomer unit, not from two different monomers. Natta confirmed this when he pointed out that co-polymers of ethylene and propylene made with Ziegler catalysts were non-crystalline and had low second-order transition temperatures.

Mainly flow characteristics of non-Newtonian fluids have been investigated during the past year. This is vital information which has not been

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adequately investigated by previous workers and ties up with the lack of information about polymerisation as a unit operation. It has been pointed out that the main difficulty encountered in the analysis of mass transfer processes (absorption, distillation and extraction) is the lack of published data. Although reliable experimental values of physical quantities are more useful than predicted ones, considerable reliance has been made in design work on estimated quantities.

Very little work, as usual, has been done on mixing. This operation is still unfashionable in scientific circles and one wonders when the industry will wake up to its importance and to the time and money that could be saved if mixers were designed from fundamental principles.

This volume altogether is packed with useful information. It is probably one of the most useful reference books revised annually and should adorn the shelf of every chemist and chemical engineer.

I.L.H.

Nuclear Radiation Measurements. By J. Sharpe. Temple Press, 1960. Pp. 75. 12s. 6d. net.

The author has tried valiantly to cram into 66 pages of text enough subject matter to fill 300 to 400 pages. The result is like a banquet at which each dish is whisked away after the first mouthful. Under the heading 'Bremsstrahlung', for example, the author decides that ' at this point it is convenient to describe another way in which charged particles may lose energy, namely in producing *x*-rays during the process of deceleration'. Actually, after a mere five more lines of data and no description we are away again to 'photoneutrons'.

One feels that this book needs a companion volume of paraphrases, since it is verging on the unreadable. The topics covered include interactions of radiations with matter, the utilisation of the liberated energy for detection purposes, basic physics of detectors, technical aspects of the measurement of specific particles, and the various ' black-box ' devices. There is a great deal that is really valuable in this book, but many students and others will prefer to pay a little more for a larger volume in which explanations are fuller. Errors are remarkably few, but I am still puzzled by the ' separation of a positive and negative ion'.

F. R. PAULSEN

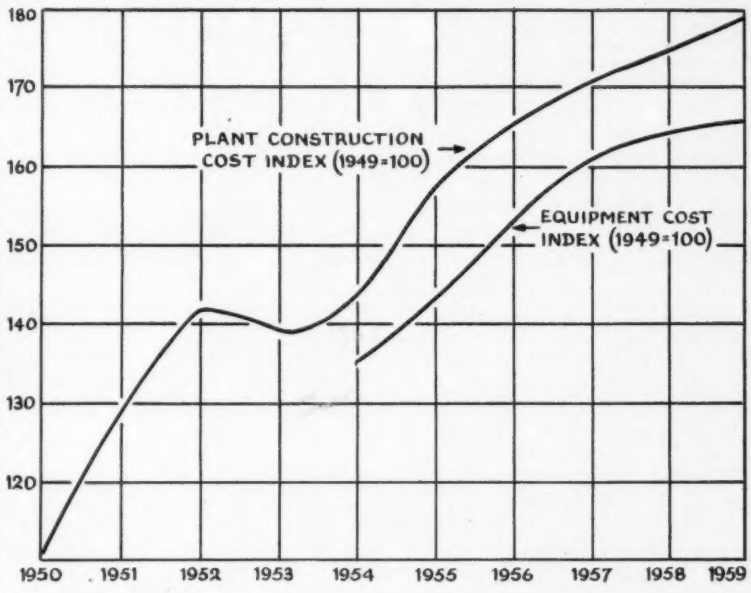
Chemical Plant Costs

The accompanying tables summarise our indices for plant construction costs over the last few years. The annual averages are shown graphically.

Since 1956 the construction cost curve is virtually a straight line showing an increase of 4 points p.a. This is as it should be, as contrast to the recession of 1952 to 1954 and the inflationary rise in 1950 to 1952.

The equipment cost curve shows even less tendency to rise. This is probably because, with no shortage of materials, delivery dates are shorter and bidding is lower than in the inflationary period.

	Plant Construction Cost Index (1949 = 100)					Equipment Cost Index (1949 = 100)				
	1955	1956	1957	1958	1959	1955	1956	1957	1958	1959
January	150.4	164.4	170.5	172.3	178.5			157.3	163.5	165.2
February	154.3	164.4	169.3	172.0	179.0			157.1	163.5	165.2
March	154.9	166.5	168.7	172.0	180.0			158.7	163.6	165.2
April	155.3	165.9	169.2	171.3	180.0			158.7	162.7	165.2
May	154.2	166.1	167.8	171.0	180.0			156.9	162.7	165.2
June	155.1	164.9	169.7	171.7	178.0			160.6	162.7	165.0
July	156.7	164.9	169.4	173.5	177.7			160.6	164.1	165.0
August	161.5	165.3	173.7	174.5	178.3			164.7	164.1	165.3
September	163.1	165.8	173.6	176.0	178.7			163.7	164.0	166.1
October	161.6	166.3	173.2	177.7	178.8			166.5	164.3	166.2
November	162.8	166.8	173.2	179.0	179.1			166.5	165.9	166.3
December	159.0	168.4	172.7	178.5	179.5			163.7	165.2	166.6
Average	157.4	165.8	170.9	174.1	179.0	143.3	153.2	161.3	163.9	165.5



Dutch storage depot

To extend better service to its European customers, Du Pont de Nemours International S.A. has set up facilities in Rotterdam for bulk storage and delivery of dimethylformamide (DMF) and 40% aqueous dimethylamine (DMA), it was announced recently.

DMF and DMA are produced by Du Pont in their Houston, Texas, works from where they are shipped by special tank vessels to the Rotterdam storage facilities. The facilities include modern tank cars and a special fleet of stainless-steel tank trucks for bulk shipment. In addition, an ample supply of 55-gal. drums is available for shipment by any convenient transportation means. Pakhuismeesteren N.V., of Rotterdam, will handle the warehousing and shipping of these chemicals.

NUCLEAR NOTES

DRAGON project

Meeting in London recently, the board of management of the O.E.E.C. high-temperature reactor project (DRAGON) approved proposals for an exchange of information between the project and the U.S. Atomic Energy Commission. The U.S.A.E.C. is developing a similar reactor to the DRAGON under a contract with the Philadelphia Electric Co. and General Dynamics Corporation.

Earlier in its meeting, the board of management had approved a £2.83-million budget for DRAGON during 1960-61, approximately one-fifth of the forecast expenditure of £13.6 million for the project's five-year period. The budget comprises £950,000 for the reactor plant and buildings, £910,000 for extramural research and development and £970,000 for the maintenance and work of the project staff at Winfrith, the site of the reactor.

A large proportion of the staff required for design and construction of the reactor experiment has already been recruited and it is expected that the remainder will be in post within the next three or four months. The staff will eventually number some 240.

Beryllium monitor

The U.K. nuclear power programme will require the use of beryllium metal and its compounds in ever-increasing quantities. In view of the toxicity of these materials it is essential to protect the health of those engaged in handling them by ensuring that the concentration of beryllium in the air of workshops and laboratories does not exceed 2 millionths g./cu.m.

The methods of analysis usually employed are time-consuming and would not give sufficient warning of a sudden or unexpected increase in the concentration of beryllium, so research workers at the A.E.R.E. chemistry division Woolwich outstation have developed a fully automatic monitor which will give the desired results in 60 sec.

The air to be sampled is drawn through a specially designed chamber in which any beryllium present is optically excited as it passes through a triggered alternating current arc. The ultra-violet radiations from this source are then resolved into their components by means of a small spectrograph which is specially designed to have a high dispersive power. The intensity of the beryllium doublet at 3,130°A., which is proportional to concentration of beryllium present in the air being monitored, is measured photo-electrically and then recorded on a chart. The results produced are quantitative over the range of concentration from 1 to 75 millionths of a gramme of beryllium/cu.m.

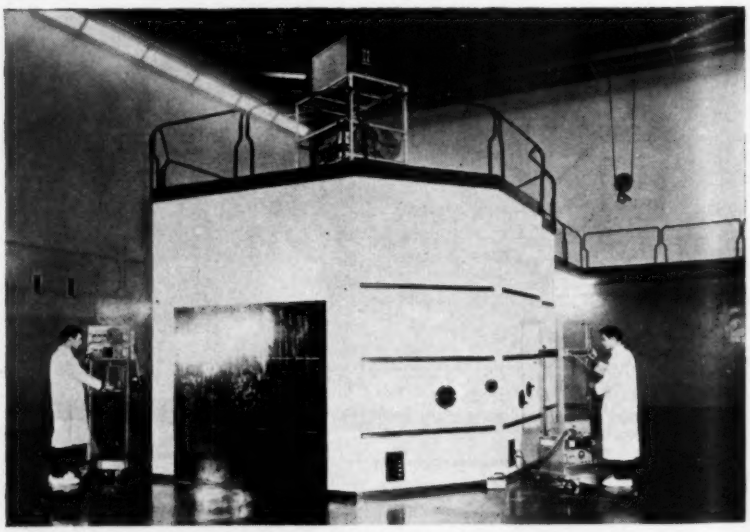
This monitor could be used for the determination of a number of elements apart from beryllium, and it is considered to have potentialities in the monitoring of atmospheres for such elements as mercury, lead, chromium, manganese, silicon, arsenic, antimony, zinc and copper.

Radioactivity measurements

The International Atomic Energy Agency has decided to undertake the measurement and analysis of samples of air, water, soil and food to help in determining the degree of radioactivity in man's environment. This will be of special importance for the agency's activities in the field of health, safety and waste disposal and its other activities in promoting the peaceful uses of atomic energy.

The work, which will be done in the agency's laboratory, now being built near Vienna, will be undertaken at the request of member States and of international organisations which have relations with the agency and in collaboration with the U.N. Scientific Committee on the effects of atomic radiation. Arrangements will also be made in the laboratory for a limited amount of training of scientists from interested member States in the relevant techniques.

Collection of samples from different areas and their analysis would indicate the amount of radioactivity and help in taking appropriate measures to reduce the radiation hazards of all peaceful atomic energy work. This is a problem in which many countries are interested but few of them possess the necessary expertise or equipment to carry out the work. Several member governments have asked the agency how it can assist them in the collection of samples and in subsequent analysis.



ITALIAN RESEARCH REACTOR

The Enrico Fermi nuclear study centre in Milan are conducting preliminary experiments with a 50,000-w. nuclear research reactor designed and built by Atomics International, a division of North American Aviation Inc. The solution-type reactor which began operating recently will be used for training and for scientific, industrial and biological research. The core where nuclear fission takes place is located inside the concrete structure. Concrete provides shielding for the operators. Exposure ports are used for inserting materials in the reactor for irradiation studies.

Controlled fusion

Important research in the long-range effort to harness hydrogen-bomb power for peaceful purposes is being accelerated at Los Alamos Scientific Laboratory in the U.S. Scientists there have developed new equipment and methods with which they will try to produce and sustain the fusion reaction. The objective of controlled thermonuclear, or fusion, research is to obtain a deuterium or deuterium-tritium plasma at a temperature of about 100 million °C. and to confine the plasma in a stable manner for a time long enough to allow an appreciable number of the nuclei to undergo fusion.

It appears possible, at least in principle, to reach a point at which the reaction will be self-sustaining: that is, when the energy release from the fusion reactions within the plasma exceeds energy losses from the system. It is beyond this point that the net power-producing plant can be foreseen.

A number of different means to this end are being studied under the Sherwood programme. All are based on the use of magnetic fields.

In the pinch approach the magnetic field used to confine the plasma is largely self-generated by strong electric currents that are caused to flow within the plasma. As the current increases the plasma is compressed, 'pinched,' into a thin filament. The plasma is heated by the electric current and by the compression.

In another approach, the *Stellarator*, coils wound around an endless tube impose a strong axial magnetic field within the tube. The charged ions and electrons are constrained to move along the magnetic lines of force and are thus kept away from the tube walls. Heating is accomplished by passing electric currents through the plasma and by modulating the confining magnetic field at the proper frequency.

Decontamination with detergent

A.E.A. research laboratories are using detergent compositions compounded to remove contamination by radioactive metals and their salts.

These compositions have been chosen to prevent re-adsorption of the contaminant during dilution and rinsing—such as can occur with acid decontamination.

The compound comes in various forms. One of the easiest to handle is a cream made by adding a thickening agent such as sodium alginate to the detergent solution. This can be used for the treatment of large objects such as aircraft. It is applied by brushing, the coating kept moist by light spraying and then removed with hot water or wet steam.

In one test, aluminium and stainless-steel surfaces contaminated with a plutonium salt solution and with a cerium-144 salt solution were exposed to the detergent for 15 min. at room temperature. At the end of the test, plutonium contamination on the aluminium had been reduced to 0.5% and on the stainless steel to 0.8%.

Dresden reactor

The U.S. Atomic Energy Commission has issued a licence permitting the operation of the Dresden (U.S.A.) nuclear power station at 50% of its rated power, or 315 Mw. This boiling-water reactor, designed and built by U.S. General Electric, reached criticality last October, under an A.E.C. limited licence authorising operation of the reactor at 1 thermal Mw. It was built for the Commonwealth Edison Co., and is the first to be completely privately financed.

The full anticipated power capacity of the reactor is 180,000 electrical kw. This corresponds to a reactor thermal power of about 630 Mw. and will produce enough electricity to supply the needs of a city of 200,000.

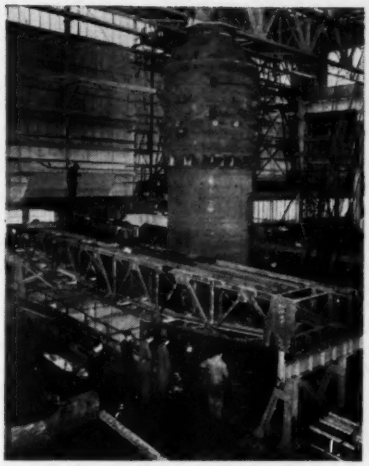
Since the first chain-reaction in October, the Dresden nuclear power station reactor has been tested through a series of criticality and twice-criticality operations; 84 fuel elements have been inserted into the reactor core and the turbine-generator unit has also been assembled and tested and is now ready for operations.

Aldermaston reactor critical

A new research reactor of the U.K.A.E.A. started operation recently. The reactor, which is known as HERALD, is situated at the Atomic Weapons Research Establishment, Aldermaston. It will be used for nuclear research work requiring intense neutron beams and for irradiation-damage studies on reactor materials.

HERALD is a light water-moderated and -cooled tank-type thermal reactor designed to operate at 5 Mw. continuously. The core of the reactor is in the form of thin plates of enriched uranium-aluminium alloy suitably spaced in water. A high flux density of thermal and fast neutrons of the order of 10^{14} neutrons/sq.cm. will be achieved.

The reactor was built for the U.K.A.E.A. by the A.E.I./John Thompson Nuclear Energy Co. Ltd.



Hunterston bridge structure made by G.E.C. Ltd.

Hunterston service machine

A further advance in the production and testing of components for Hunterston nuclear generating station was made recently when the pressure vessel for the first service machine was installed in the Erith engineering works of the General Electric Co. Ltd. This is to enable the internal mechanisms to be fitted and checked, as part of a comprehensive series of tests of all operations of the machine which is to be carried out at Erith before its subsequent installation on reactor A at Hunterston.

It will be recalled that the two Hunterston reactors will each use a charge machine operating from below, leaving the area of the top shield free for maintenance operations. The service machine is installed above this floor and is capable of performing all normal reactor maintenance duties, together with a number of emergency operations. With few exceptions, these operations can be carried out with the reactor under pressure and on load.

The machine consists essentially of six specialised units contained in a pressure vessel, which is mounted on a movable bridge with longitudinal and cross travel, so that it can be positioned over any one of the 208 standpipes connecting with the reactor. Two identical units are used for control-rod and motor replacement, another pair are used for removal of distance tubes and control rods in the event of cable breakage, one carries a set of telescopic tubes for the insertion of thermocoupled fuel elements, and the sixth has telescopic tubes to link with any fuel channel for more general purposes.

Orders and Contracts

Furnaces for plutonium production

The General Electric Co. Ltd. received a further contract from the U.K.A.E.A., Risley, for electric furnaces for use in the production of plutonium metal. This order covers reduction and fluorination furnaces.

The fluorination furnace is rated at 10 kw. and is of the horizontal front-loading type, complete with muffles, the inner surface of the muffles and doors being lined with platinum. A forced cooling system is incorporated to enable the charge to be cooled within a stipulated time.

The furnace for the reduction process is rated at 50 kw. It is of a bell-type design and has a forced cooling system similar to the fluorination furnace.

Electrical equipment supplied includes regulating transformers, temperature control gear and the necessary switchgear.

Pneumatic handling equipment

Baker Perkins Ltd. have secured a contract worth about £500,000 for pneumatic handling and mixing equipment which will be installed at Shell Chemical Co. Ltd.'s new polyolefines plant at Carrington.

The main contractors for the plant are Matthew Hall & Co. Ltd.

Iron ore sintering plant

Head Wrightson Iron & Steel Works Engineering Ltd. have received an order from the Skinningrove Iron Co. Ltd. for the design and construction of a materials handling and iron ore sintering plant at their works at Carlin How, Yorks.

The plant is designed to produce ultimately 7,000 tons/week of self-fluxing blast furnace sinter from a mixture of imported and home ore fines. The total value of the work involved is approaching £700,000.

Incorporated in the plant will be equipment for automatically feeding and controlling the proportions of raw materials, limestone handling equipment, a coke grinding mill, raw materials mixing equipment, a continuous sintering machine with all ancillaries, a forced-draught sinter cooler and conveying equipment both for raw materials and for delivering the sinter to the existing blast furnace bunkers.

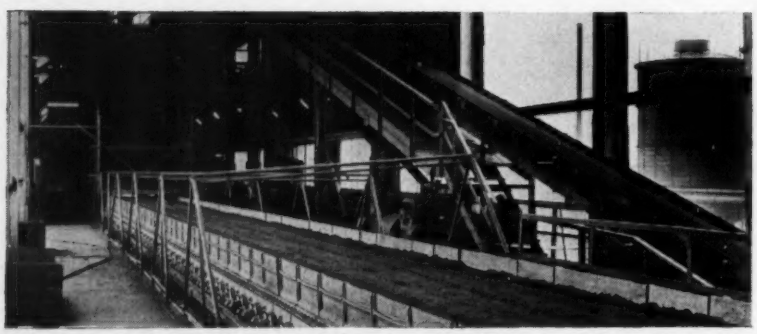
Chemical plant expansion

Plans are in hand to build three new major plants at the works of British Hydrocarbon Chemicals Ltd. at Grangemouth, in Scotland. One of the plants will more than double the existing capacity for the manufacture of butadiene. The other two new plants are for the manufacture of methanol and ethylene dichloride.

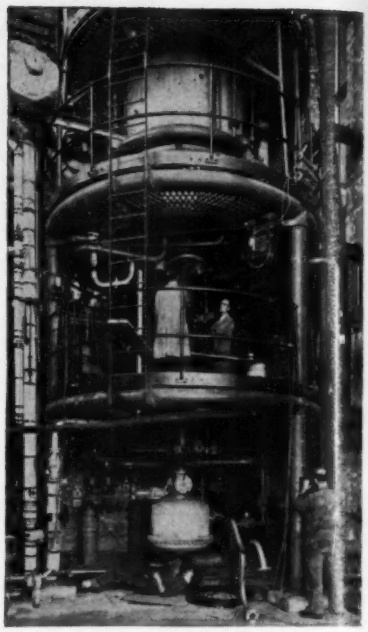
It is planned to commission each of the three new plants during 1961. The total investment in the three plants is approximately £5 million.

The company is jointly owned by the British Petroleum Co. Ltd. and the Distillers Co. Ltd.

Chemical Construction (G.B.) Ltd. have been awarded the contract for the design, engineering and construction of the methanol plant which will use hydrocarbon gases from the ethylene plant as feedstock. These hydrocarbon gases will be reformed to carbon dioxide, carbon monoxide and hydrogen in ratios suitable for the high-pressure synthesis of methanol. The crude methanol will be refined by extractive distillation to produce a high-purity material suitable for use in the manufacture of resins, antifreeze and various esters, solvents, etc.



Sinter plant installation typical of the type of equipment to be supplied to the Skinningrove Iron Co. Ltd.



COKE GASIFIER

The experimental coke gasifier, which is being operated by Constructors John Brown Ltd., gasifier division, under Ministry of Power contract, being prepared for a trial run. The gasifier converts coke into 'synthesis gas', a carbon monoxide hydrogen mixture used in the manufacture of synthetic fuels and chemicals. The cooling system and the slag dispersal system are based on the use of pressurised water circulated by 'Megator' pumps.

The contract for the butadiene extraction plant, which covers engineering design, procurement of materials and equipment and construction of plant, has been placed with Fluor Engineering & Construction Co. Ltd. The contract for the ethylene dichloride plant has been placed with the Lummus Co. Ltd.

Crude oil sweetening plant

Foster Wheeler Ltd. has been awarded a contract for the design, supply and construction of a crude oil sweetening plant to handle 250,000 bbl./day of crude oil, to be erected at Kirkuk, Iraq, for the Iraq Petroleum Co. Ltd. This plant will be similar to 11 plants of smaller capacity previously designed and erected by the company at Kirkuk, and is required primarily for the removal of hydrogen sulphide together with light hydrocarbons from the crude oil before pumping through the pipeline to the Mediterranean coast.

It is also necessary to take care of the increased production of crude oil from the Kirkuk oilfield, for which

arrangements are already in hand in connection with the expansion of the existing pipeline from Kirkuk to the Mediterranean coast.

The value of the contract is over £500,000. All design work is to be carried out and substantially all materials will be supplied from the U.K.

Research reactor

The Dutch Nuclear Research Centre (Reactor Centrum Nederland) has placed an order for a 10-kw. JASON research and training reactor with Hawker Siddeley Nuclear Power Co. Ltd.

The JASON, which will be operating in August, is to be installed as a low flux reactor at Petten, north of Amsterdam, and will be complementary to the high flux reactor under construction there. It will be the first small British reactor on the continent.

Turbo-alternator

Richardsons Westgarth (Hartlepool) Ltd. have received an order for the third 120-Mw. turbo-alternator for Richborough power station in Kent.

The turbines will be of the three-cylinder high-pressure reheat type and the alternator will be hydrogen-cooled.

Richborough power station is due to be completed in 1964.

Fifty-one contents gauges

Orders have been received by Firth Cleveland Instruments Ltd., from the Shell International Petroleum Co. Ltd. on behalf of Shell Refining Co. Ltd., for *Gilbarco-Firth Cleveland* automatic tank contents gauges to be fitted to 51 petroleum storage tanks.

The tanks are at the South, Tranmere and Hill sites at Shell's Stanlow refinery, and at the Shell Haven refinery in Essex.

Each tank is to be equipped with a *Gilbarco-Firth Cleveland* electronic tank contents gauge, connected to one of five *Gilbarco* remote reading receivers. In addition, equipment for the remote reading of the average temperature of the tank contents is to be installed.

Sulphuric acid projects

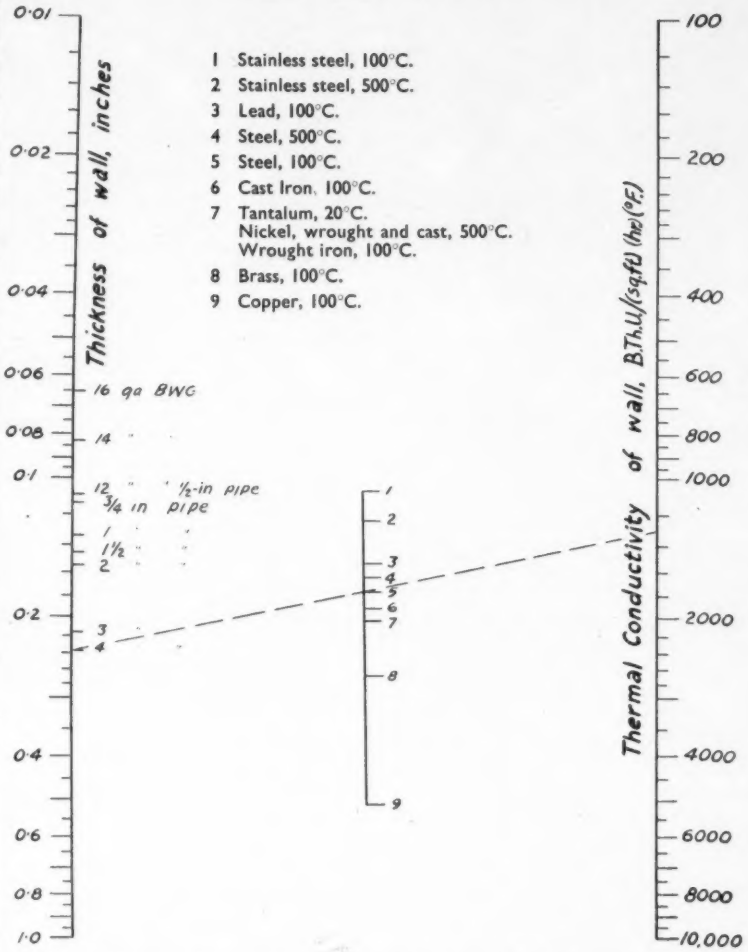
Chemical Construction (G.B.) Ltd. have been awarded two major contracts by the newly formed Albatros Sulphuric Acid & Chemical Works at Vlaardingen, Holland. This new company is jointly owned by Albatros Superfosfaatfabrieken N.V. of Utrecht, member of the Royal Dutch Salt group, and Cyprus Mines Corporation of Los Angeles.

The projects involve a complex sulphuric acid contact plant with a capacity of more than 100,000 MT p.a., designed to take sulphur dioxide gas from pyrites and from a unique plant of *Chemico* design which is to decompose 56% sulphuric acid refinery sludge coming from the adjacent Shell refinery.

Total value of the two plants, completely installed, will be about £650,000.

Thermal Conductivities of Metal Walls

By Prof. D. S. Davis*



The accompanying nomogram, which was constructed by means of well-known methods,[1] extends considerably the utility of standard data[2] on the thermal conductivities of metal walls. The chart consists of parallel logarithmic scales for thermal conductivity and thickness of pipe wall and a central scale of gauge numbers for the various metals. The thickness scale is also provided with points for many of the common tubes and pipes and thus saves the reader the trouble of looking up values in handbooks.

The broken index line shows that at 100°C. the thermal conductivity of 4-in. Schedule 40 steel pipe is 1,300 B.Th.U./sq.ft.hr.°F.

**University of Alabama.*

REFERENCES

[1] D. S. Davis, 'Nomography and Empirical Equations,' Chap. 10. Reinhold Publishing Corporation, New York, 1955.

[2] M. W. Shellenbarger, *Chem. Eng.*, 1956, **63** (9), 222.

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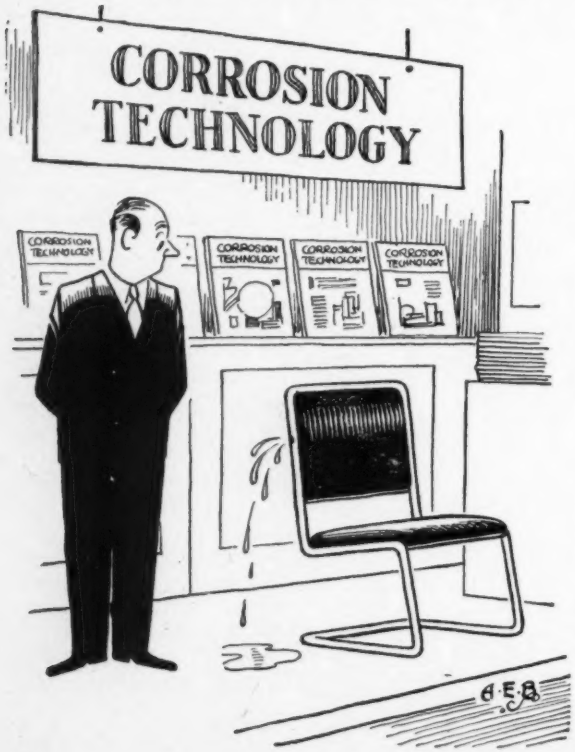

CORROSION EXHIBITION?

We reprint this cartoon which appeared in the 1959 Corrosion Exhibition catalogue to remind you that although the 1960 Exhibition will not open until November 29, it is advisable to reserve your stand *now*. Already most of the Empire Hall, Olympia, has been booked. To ensure the widest possible choice of the remaining stands, applications must be received now.

THE CORROSION EXHIBITION

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Personal Paragraphs

★ Following the acquisition by Metal Industries Ltd. of Lancashire Dynamo Holdings Ltd. the following board changes were announced: **Sir Charles Westlake,** the chairman, and **Mr. J. Black,** the deputy chairman of Metal Industries, have been appointed chairman and deputy chairman respectively of Lancashire Dynamo Holdings. **Lt.-Col. G. S. Marston** has resigned as chairman, managing director and director of Lancashire Dynamo Holdings. **The Earl of Halsbury** retains his office as vice-chairman of Lancashire Dynamo Holdings.

★ **Mr. E. S. Sellers,** formerly professor of chemical engineering at the University College of Swansea, has joined the British Petroleum Co. He becomes manager of the petroleum division of the company's Sunbury research centre in succession to **Mr. W. M. Catchpole.** Mr. Sellers previously served with the company in Iran from 1935 to 1938.

★ Shell Chemical Co. announce the appointment of **Mr. G. W. Loynd** as superintendent (new plants), Carrington works, near Manchester. He joined the group in 1945 as a trainee. Since July 1958 he has been at Carrington as departmental manager (new plant), which post he leaves for his new appointment.

★ **Mr. W. Padley,** C.M.G., O.B.E., has been appointed to the board of Metal Industries Ltd. He will relinquish his position as managing director of Brookhirst Igranic, M.I.'s electrical subsidiary, and will be succeeded in that post by **Mr. A. B. Vickery,** O.B.E.

★ **Dr. B. H. Barker,** president of the Colorado School of Mines Board of Trustees, has been elected president of the American Association of Petroleum Geologists. He is vice-president and director of the Frontier Refining Co. He will assume direction of the 15,500 member organisation at the end of the 45th annual meeting of the association at Atlantic City, New Jersey, this month.

★ **Mr. E. F. Wentworth** and **Mr. F. M. Pyzel** have been appointed presidents of Foster Wheeler Corporation. Mr. Wentworth, who joined the firm in 1941, has been general attorney in charge of the legal department since 1950. Mr. Pyzel joined the company in 1944 as director of process development in the firm's engineering and research department. In 1959 he was made director of the process development department.

★ **Mr. W. Davis** will receive the James T. Grady Medal for distinguished reporting of chemical progress during the 137th national meeting of the American Chemical Society. He is the director of Science Service, a news syndicate serving more than 10 million readers of daily newspapers, and has been interpreting scientific discoveries and advances to the public since 1920.

★ **Mr. R. C. Nelson,** marketing manager of the General Products group of Du Pont, has been promoted to sales director of the company. He has had 16 years' experience in research and export sales with the company. **Mr. N. P. Rockwell,** assistant export manager of Du Pont's industrial and biochemical department, has been transferred to the Swiss company as marketing manager for agricultural and industrial chemicals and will take over some of Mr. Nelson's former duties.

★ **A. H. Wilson,** F.R.S., **C. F. Kearton,** O.B.E., and **W. Gerard Daroux** have been appointed to the board of Pinchin, Johnson & Associates Ltd. a subsidiary of Courtaulds Ltd.

★ **Mr. M. Wormald** has been appointed London area manager of Firth Cleveland Pumps Ltd. He was previously with the technical sales department of the Esso Petroleum Co. Ltd.

★ **Mr. T. B. McLaren** has been appointed superintendent of Shell Chemical Co.'s Stanlow chemical plant, Ellesmere Port. He has been with the group since 1947.

★ **Mr. G. Liley** has been appointed to the board of British Lead Mills Ltd., a member of the Firth Cleveland group. He was formerly an executive director of the company.

★ **Dr. M. E. Haine** has been appointed director of A.E.I. Harlow research laboratory. He succeeds **Dr. G. W. Sutton,** who has retired. Dr. Haine was formerly manager of the laboratory.

★ **Mr. J. M. Kershaw,** director of development and market research of Monsanto Chemicals Ltd., has been appointed to the board of the company. He joined the company in 1946 and has been responsible for a number of special development projects, including the construction of the company's new factory at Fawley.

★ **Mr. G. S. G. Blunt** has joined the technical sales staff of the process control division of Bailey Meters & Controls Ltd.

★ **Mr. T. J. Thomas,** who has been the manager of the polymer development section of Dunlop's research centre, has been appointed technical manager of the company's composition division.

★ The Kelvin Gold Medal for 1959 has been awarded to **Sir Geoffrey Taylor,** F.R.S., at the Institution of Civil Engineers. The medal is awarded triennially as a mark of distinction in engineering work of investigation.

★ **Mr. L. C. Richards,** until recently chief engineer of A.E.I. Ltd. transformer division at Manchester, has become chief engineer to Heavy Electricals Ltd., India, on his transfer to A.E.I. Overseas Ltd.

★ **Mr. L. R. E. Appleton** has been appointed managing director of Fairey Engineering Ltd. and **Mr. P. J. Duncton,** a director of the company, has been appointed general manager of the Heston factory.

★ **Prof. C. Salvetti,** the Italian nuclear phycisist, has been appointed director of the International Atomic Energy Agency's division of research and laboratories. He comes to the agency from the Italian Government's nuclear centre, Ispra, of which he was director general.

★ **Mr. C. H. Sommer** has been elected president of Monsanto Chemical Co., U.S.A., in place of **Dr. C. A. Thomas,** who has been elected board chairman. The previous chairman, **Mr. E. Monsanto Queeney,** son of the company's founder, remains a member of the board and chairman of the finance committee. Mr. Sommer was elected executive vice-president and board member in 1949.

★ **Field Marshall Sir William Slim** has been appointed as an additional director of I.C.I. Ltd., acting in a non-executive capacity.

★ The Bronze Medal of the Institution of Public Health Engineers has been awarded to **Mr. W. M. T. Boby,** managing director of William Boby & Co. Ltd., for his paper 'Desalting of Saline Waters by Electrodialysis,' which has been selected as the best recorded paper in the Institution's journal during 1959.

World News

HUNGARY

Spherical gas reservoirs

There is an essential difference between high-pressure spherical steel gas reservoirs constructed in Hungary and similar plant manufactured in other parts of the world; while in other countries expensive supporting steel structures are used, in Hungary simple ferro-concrete wall-pilaster supporting structures are made. These two-joint ferro-concrete wall-pilasters (or sloping lags) are 30 cm. thick and only 100 cm. wide at the head. The shell of the steel sphere is supported on a 4.5-m.-radius circle at a spacing of 120° each, with the projection of their vertical planes enclosing angles of 120° and thus being capable of performing joint-movements in one direction only.

PHILIPPINES

Chemical plant

Three technical executives of Union Carbide International have been to Manila for an investigation of local conditions relating to the establishment of an integrated multiple chemical plant. They have in mind a carbide-caustic soda-polyvinyl chloride operation to be located in Iligan.

The plant would be self-sufficient in raw materials and ensure a steady flow of these chemicals to local end-users. It would be a joint venture of Union Carbide and the Guevara interests.

UNITED STATES

High-density polythene plant

Allied Chemical Corporation is to build a high-density polythene plant at Orange, Texas.

Expected to be completed late this year, the plant will form the first unit of a supplement to the company's polythene production at Tonawanda, N.Y. Output at the latter location was increased 25% last year and will be further increased during 1960.

The new polythene unit at Orange will adjoin an ethylene derivative plant operated by the company's nitrogen division.

JAPAN

Reforming units

A 6,000-bbl./day *Houdriformer* catalytic reforming unit and an 8,000-bbl./day hydrosulphurisation unit are to be built in Mizushima by Nippon Mining Co. Ltd., under licence from Houdry Process Corporation.

The *Houdriformer* will process 6,000 bbl./day of desulphurised petroleum naphtha with the remaining 2,000 bbl./day from the desulphuriser used for jet fuel blending and speciality naphthas.

NORWAY

New paper mill

A joint British-Norwegian pulp and paper mill for the production of corrugating medium from hardwoods will be erected at Sande, on the Oslo fjord, in Norway. The two concerns responsible for the project, which will cost £2 million and have an initial output of 300,000 tons p.a., are the Reed Paper Group of London and Sande Træsleperi A/S., of Oslo.

According to the managing director of Sande Træsleperi, the largest producer of mechanical pulp in Norway, the negotiations between the two firms have been going on for a couple of years.

Work on the new factory will be started as soon as the Ministry of Industry has licensed the project, and it is hoped to have the building more or less completed before next winter. The factory will give work to 100 persons, as well as increased employment in forestry and transport.

The business will be led by a joint British-Norwegian board of directors.

Nuclear laboratory

The Norwegian company, Noratom A/S., which is an industrial nuclear energy company, has signed a contract with the Egyptian Nuclear Committee for the supply to Egypt of a complete laboratory for the production of radioactive isotopes for medical and technical purposes. The amount of the contract is 2.5 million kroner (£125,000). The technical equipment will be produced in Norway.

FRANCE

Natural gas

Since 1957, Gaz de France have been working on the construction of a grid system for transporting natural gas from its source at the foot of the Pyrenees. The construction of the pipeline has been a major engineering feat, and many obstacles have had to be overcome. In the Garonne, the Dordogne, the Loire and the Saône, 36 rivers and streams, 300 main highways, 27 railway tracks and a number of forests and mountains have had to be traversed.

The work throughout has progressed at a rate of 1 km./day and by the end of 1958 the line arrived at Nantes; Lyons was reached in July and Paris in December 1959. The project is scheduled to be finished by the end of 1960 when more than 2,500 km. of pipeline will have been laid and France will then possess the longest grid for transporting natural gas in Europe.

ITALY

Propylene oxide plant

The construction of a production facility for propylene oxide and derivatives is planned by SpA. Celene, a company jointly owned by Union Carbide and Societa Edison.

It will be at Priolo, Sicily, adjacent to Celene's other production facilities and will have an initial capacity of 25 million lb. p.a.

The basic raw materials for the new expansion will be obtained from the adjoining plant of SINCAT.

AUSTRALIA

Gasworks

A gasworks is to be built at Geelong, near Melbourne, by Humphreys & Glasgow Ltd., of London. The works, due to go into operation next year, will consist of two *Onia-Gegi* catalytic reforming units, each producing 1.5 million cu.ft./day of town gas.

The units will use tail gases piped from a Shell oil refinery five miles away. As an alternative feedstock, liquefied petroleum gas, for which storage facilities are being installed, will ensure continuous output when the refinery is shut down for maintenance.

The works will be the first in Australia to use the *Onia-Gegi* process in which refinery gases of high calorific value, but varying quality, are combined with steam in the presence of a nickel catalyst to yield hydrogen gas.

This is enriched with additional refinery gas to a calorific value of 500 B.Th.U./cu.ft., and in its final composition is interchangeable with normal coal gas.

£ s d

CHEMICAL PLANT COSTS

Cost indices for the month of March 1960 are as follows:

Plant Construction Index: 179.9

Equipment Cost Index: 168.9

(June 1949 = 100)

£ s d